Children's Ability to Generate Novel Actions

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Declaration

I hereby declare that this thesis has been composed by myself and has not been accepted in any previous application for a degree. The work presented in this thesis is my own work, except where stated. All sources of information have been acknowledged by means of reference.

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Abstract

Social learning has given us insight into how children learn actions from others across different domains (e.g., actions on objects, pretend play, and tool use). However, little research exists to confirm whether young children can generate their own novel actions. Three different settings were chosen to offer a varied investigation of children's ability to generate novel actions: generating multiple actions with novel objects; generating iconic gestures in order to communicate; and generating pretend actions using object substitution.

Generating multiple actions with novel objects

The Unusual Box test was developed to investigate children's ability to generate multiple actions with novel objects (Chapter 2). The Unusual Box test involves children playing with a wooden box that contains many different features (e.g., rings, stairs, strings), and five novel objects. The number of different actions performed on the box and with the objects (i.e., fluency) was used as a measure of their individual learning. Positive correlations between the fluency scores of 24 3- and 4-year-olds on the Unusual Box test and two existing measures of divergent thinking were found. Divergent thinking relates to the ability to think of multiple answers based on one premise. Furthermore, a large range of fluency scores indicated individual differences in children's ability to generate multiple actions with novel objects.

In addition, 16 2-year-olds were assessed on the Unusual Box test, twice two weeks apart, to investigate test-retest reliability and the possibility that the Unusual Box test could be used with children younger than 3 years. A strong positive correlation between the scores on the two assessments showed high test-retest reliability, while individual differences in fluency scores and the absence of a floor effect indicated that the Unusual Box test was usable in children from 2 years of age.

Generating iconic gestures in order to communicate

Children's ability to generate iconic gestures in order to communicate was assessed using a game to request stickers from an experimenter (N = 20, Chapter 3). In order to get a sticker children had to communicate to the experimenter which out of two objects they wanted (only one object had a sticker attached to it). Children's use of speech or pointing was ineffective; therefore only generating an iconic gesture was sufficient to retrieve the sticker. Children generated a correct iconic gesture on 71% of the trials. These findings indicate that children generate their own iconic gestures in order to communicate; and that they understand the representational nature of iconic gestures, and use this in their own generation of iconic gestures.

Generating pretend actions using object substitution

In order to determine whether children are able to generate their own object substitution actions and understand the representational nature of these actions, 45 3- and 4-year-olds were familiarized with the goal of a task through modelling actions. Children distinguished between the intentions of an experimenter to pretend, or try and perform a correct action. Children mainly imitated the pretend actions, while correcting the trying actions. Next, children were presented with objects for which they had to generate their own object substitution actions without being shown a model. When children had previously been shown pretend actions, children generated their own object substitution actions. This indicates that children generate their own object substitution actions, and that they understand the representational nature of these actions. An additional study with 34 3-year-olds, revealed no significant correlations between divergent thinking, inhibitory control, or children's object substitution in a free play setting, and children's ability to generate object substitution actions in the experimental setting.

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Chapter 1

General Introduction

1.1 Learning in young children

Children spend most of their time learning new things; through play, reading, studying, watching television, and so on (Hofferth & Sandberg, 2001). When children reach primary school age, they spend about 30 hours a week in school and many children take part in extra-curricular activities outside school hours (Hofferth & Sandberg, 2001). However, more and more emphasis is being placed on children's learning and development before they go to primary school. The Curriculum for Excellence (Scottish Executive, 2004), the national curriculum for schools in Scotland, provides guidelines for children's learning and development from the age of 3. Furthermore, The Statutory Framework for the Early Years Foundation Stage (The Department for Education, 2012) was developed especially to provide standards for learning and development for children from birth to five years old. The Early Years Foundation Stage mentions 7 learning and development requirements - communication and language; physical development; personal, social and emotional development; literacy; mathematics; understanding the world; and expressive arts and design - which should safeguard and promote children's welfare. The guidelines include that teachers should consider individual needs and interests, thereby emphasizing that each child's learning process is unique. Furthermore they encourage a child-directed teaching strategy, emphasizing the importance of exploration, active learning and creative thinking. This indicates the importance of child-directed learning, in which children take a lead in what they learn.

1.1.1 Theories of learning

Several different theories have been proposed in the past to explain how children learn. According to Piaget’s theory of cognitive development (Piaget, 1952) children learn to organize and interpret information presented to them by creating cognitive frameworks or schemata. The theory of cognitive development describes two processes through which children learn about the world around them; through accommodation and assimilation. When a child is presented with information that is conflicting with an existing schema, the child will have to change that schema to account for the new information. This process is called accommodation. An example of accommodation is if a child believes that all animals with four legs are dogs, but then discovers that there are other animals which also have four legs but are not dogs. The child will then have to change the current schema to accommodate for the fact that other animals can also have four legs. Assimilation occurs when a child includes new information to an existing schema without having to change the schema itself. An example of assimilation is if a child encounters a new breed of dog that s/he has not seen before, and assimilates this new dog type within the current schema of what a dog is. When a child’s current schemata are capable of explaining the information presented to him/her, equilibrium is said to occur.

Cognitive development takes place when our schemata are adjusted or new schemata are formed to accommodate new information presented to us. According to Piaget, there are four stages of cognitive development that all children go through during childhood. The first stage, called the sensory-motor stage, lasts approximately the first 18 months of life. The most important schemata children learn during this stage are object permanence (i.e., an object continues to exist even when it cannot be seen anymore) and the idea of one sensory-motor space (i.e., space becomes a single objective in which all objects are situated, including one's own body; Piaget, 1962). The second stage is called the pre-operational stage, and lasts up until around 7 years of age. Children's play in this stage is limited by egocentrism, in the sense that they cannot distinguish between their own perspective and those of others. During this stage children learn the principle of conservation and in effect the principle of reversibility (i.e., if we pour water from one glass into another glass with a different shape it will still contain the same amount of water). In the third or concrete operational stage (until around 12 years) children learn to think logically about objects and events, and are able to classify and order objects. However, children's cognitive development is still limited to objects in space, and it takes until the fourth stage, the formal operational stage, before they can reason on hypothesized operations (from 12 years until adulthood).

According to the theory of cognitive development, progression to a new developmental stage is a prerequisite for learning. This means that learning can only take place when a child has reached the appropriate stage of cognitive development to take in the new information. The progression of a child towards the next stage in cognitive development can be facilitated through biological factors (maturation), individual experience and social learning (Piaget, 1964). Maturation refers to the development of the nervous system which still takes place during childhood and into adolescence. According to some studies the sudden increase in cognitive skills can be attributed to specific changes in the nervous system which occur around the same time (e.g., Diamond, 1990; Goldman-Rakic, 1987). In addition, physical experience with objects allows us to gain an understanding about characteristics of objects such as weight and texture, by comparing objects with different characteristics. These experiences can be consolidated through social transmission, e.g., physically showing children the characteristics of objects or educating them in another form, such as through pictures or through speech. However, according to Piaget we cannot proceed to the next stage of development without having understood the concepts in the previous stages. That is, an equilibration of the schemata in the previous stage is required before a child can continue to a next stage.

Piaget’s theory of cognitive development has been influential in providing a foundation for other learning theories. For example, the experiential learning theory (Kolb, 1984) draws upon the idea that learning is a process rather than an outcome as proposed by behavioural theories of learning (e.g., Skinner, 1948; Thorndike, 1898; Watson, 1913). In classical behaviourist experiments such as the Skinner box (Skinner, 1948) and Thorndike’s puzzle box (1898), animals learned to execute certain patterns of behaviour to reach a goal (e.g., press a lever a certain number of times to receive food). From the behaviourist’s point of view learning takes place when individuals make the link between the individual’s own behaviour and its outcome. Kolb (1984) argues that when following these behavioural learning theories learning is quantified by the number of fixed ideas or behaviours an individual has accumulated. The experiential learning theory however argues that ideas are not fixed but are formed and reformed through experience (Kolb, 1984). Similar to Piaget’s theory, experiential learning theory stresses the interaction between the knowledge an individual has already acquired and the current environment or experience in which this knowledge is reinterpreted. Therefore, ideas are not quantifiable because each idea can be influenced by new experiences and in that sense cannot be seen as separate entities. Learning according to the experiential theory is the process of acquiring new knowledge, and transforming existing knowledge, through experience.

Piaget’s theory of cognitive development and the experiential theory acknowledge children’s individual experience as well as social transmission as a source of learning; however it is unclear what the specific contributions of either are in the process of learning. Social learning theories, such as Vygotsky's dialectical theory (1934) and pedagogy theory by Csibra and Gergely (2006), provide a framework of how social transmission aids learning.

Vygotsky's dialectical theory (1934) is perceived as the main opponent to Piaget's theory of cognitive development. This theory is predominantly focused on the importance of other people in the process of learning, also referred to as social learning. According to Bandura (1971), social learning encompasses both direct experience through observing the behaviour of others which might not necessarily have been intended as learning moment (e.g., observing the consequences of driving under influence when a drunk driver has crashed his car) as well as deliberate modelling of desired behaviour (e.g., showing a child how to write).

Although Vygotsky agrees with Piaget that we learn through interacting with our environment, he argues that learning *precedes* development rather than the other way around. According to Vygotsky's dialectical theory, an individual's current state of development is enhanced when confronted with new tasks just out of reach of his/her present abilities. The gap between our current development and what we can accomplish with the help of others is called the zone of proximal development (ZPD). The ZPD is not fixed but can increase or decrease depending on the person and the task. This means that some children are able to perform a bigger range of tasks with help of more experienced others compared to other children. Learning takes place when children are able to perform these new tasks with the help of others. However, in congruence with Piaget's theory, Vygotsky's dialectical theory also acknowledges stages in development, in the sense that children cannot learn tasks which fall outside the ZPD until they have mastered the tasks they can learn within the ZPD.

Pedagogy theory (Csibra & Gergely, 2006) proposes that children have an innate ability to learn from other people (‘teachers’) through their understanding of ostensive and referential cues. Ostensive cues are behaviours which make clear that a teacher has the intention to teach, or if initiated by the child, the request or intention to learn. Examples of ostensive cues are making eye contact, and using infant-directed speech to address the child (Gergely, Egyed, & Király, 2007). Referential cues are behaviours which make clear about which object or situation of interest knowledge is being transferred. Examples of referential cues are pointing or shifting gaze towards the referent (Csibra & Gergely, 2006).

The innate ability to understand ostensive and referential cues is hypothesized to be derived from the evolution of tool use (Csibra & Gergely, 2006). According to this theory, the first tools used by humans had a clear purpose in helping towards a specific goal. The connection between the use of the tool and the outcome were clear. While tools were initially seen as temporary utilities which were discarded when the goal was reached, at some point our ancestors started to keep the tools with them for later use such that tools obtained permanent functions. This allowed humans to search for tools that served a specific purpose, which led the way to creating tools that could help in fabricating other tools. This important change in which tools were used in chains, whereby the end goal cannot immediately be derived from the initial tool use, is hypothesised to be the reason why pedagogy and the use of ostensive and referential cues evolved. When the end goal of behaviour is opaque and one cannot derive the direct function of this behaviour from observation alone, pedagogy can help to give information about the goal and how the observed behaviour can lead to that specific goal. Once this mechanism of pedagogy was established it allowed for use outside the scope of tool use. Consequently it allowed for knowledge transfer as we see it today, in which not only specific behaviours are being taught in order to survive, but also behaviours that do not seem to have a direct adaptive value, such as arbitrary conventions and traditions.

Pedagogy theory acknowledges that it only focuses on a specific kind of social learning, i.e., the intentional knowledge transfer between two people (‘teacher’ and ‘learner’). More specifically, pedagogy theory only focuses on transferring existing knowledge and does not consider behaviour that facilitates the emergence of new knowledge. Similarly, Vygotsky’s dialectical theory only focuses on how children learn through other people who convey knowledge that they already have. Therefore, this theory also cannot explain how new knowledge is created.

There are two ways in which new knowledge can be created. The first way is when errors are made in imitating behaviour (unsuccessful imitation), by which in consequence a new behaviour is created or a different outcome is reached (Rendell *et al.*, 2010). For example, someone may intend to use a hammer to put a nail into a wall as modelled but accidentally misses and consequently makes a hole in the wall. Although unsuccessfully imitating the initial behaviour, it does show a new way in which a hammer could be used, thereby adding new knowledge to the current knowledge repertoire. The second way in which new knowledge can be created is through exploration, in which new knowledge is intentionally searched for by trying out new behaviour (March, 1991). It includes behaviours such as experimentation, play, being flexible, and risk taking (March, 1991). Since exploration is an intentional process of knowledge creation while unsuccessful imitation is merely a by-product of an error, exploration is generally the focus of interest when investigating knowledge creation (e.g., Charney, Reder & Kusbit, 1990; Gupta, Smith & Shalley, 2006; March, 1991; Tani & Yamamoto, 2002). Therefore, in this thesis only exploration is considered when talking about processes which create new knowledge.

Social learning theories emphasize the importance of interaction with others in the process of learning; however this does not provide the full picture. Learning can occur both in social settings as well as in non-social settings through exploration, also referred to as individual learning (Vriend, 2000). The theory of cultural evolution (Mesoudi, Whiten & Laland, 2004) provides a framework in which both the individual contributions of social learning and individual learning are apparent.

In accordance with Darwin's theory of evolution (Darwin, 1859) the theory of cultural evolution proposes that human cultural traits (e.g., knowledge, skills, behaviours) evolve over time through *variation, competition,* and *inheritance* (Mesoudi *et al.*, 2004). Variation refers to the variety of cultural traits that exist. Variation increases when new ideas or behaviours are introduced, for example via exploration, or when existing traits are modified (Mesoudi *et al.*, 2004). A variation of cultural traits is required to allow us to adapt to changing environments. Only those variations survive which are useful for our species to survive. Competition is important in this selection process to filter out those variations that are not viable so that only the best cultural traits survive. This is similar to the 'survival of the fittest' phenomenon in Darwin's theory of evolution. Finally, inheritance takes place when cultural traits are socially transmitted to other people who have not learned these traits yet. Vertical transmission takes place when traits are transmitted from one generation to the next, while during horizontal transmission traits are transmitted to individuals within the same generation (Cavalli-Sforza & Feldman, 1981). Inheritance is crucial for cultural evolution because it allows us to learn from the experiences of others, which saves time and can even make the difference between life and death (e.g., learning what foods are edible; Galef Jr & Laland, 2005).

According to the theory of cultural evolution, both individual learning and social learning are important learning mechanisms. On the one hand, individual learning allows for the creation of new knowledge which is important to increase the variation of cultural traits. This allows us to adapt to new environments, and search for solutions to problems that might threaten our existence (e.g., climate change, disease epidemics). On the other hand, social learning allows for cumulative learning, in which new knowledge builds on and integrates existing knowledge (Maton, 2009). By combining social and individual learning, we are able to build upon what is known and create new knowledge which we most likely would not be able to produce without previous knowledge (e.g., specialized technologies such as the computer). This allows for innovation, when new ideas are introduced that result in increased performance of the society (Rogers, 1998).

1.1.2 Divergent thinking, creativity, and generation of new ideas

An important cognitive skill in the generation of new ideas is divergent thinking. Divergent thinking is defined as the ability to think of ideas beyond what is currently available and to search for new alternatives (Guilford, 1959). Terms such as ‘brainstorming’ or ‘thinking outside the box’ are common terminologies to indicate divergent thinking. Divergent thinking has been argued to be an important cognitive skill for creativity, with high divergent thinking predicting creative achievement (e.g., Kim, 2006; Runco, Millar, Acar, & Cramond, 2010).

Creativity has been defined in many different ways. For example, Perry-Smith & Shalley (2003) define creativity as “generating new ways to perform their work, by coming up with novel procedures or innovative ideas, and by reconfiguring known approaches into new alternatives" (p. 90). Smith (2005) argues that a creative activity "must generate a valuable or, at least, appropriate product" (p. 294). Glück, Ernst and Unger (2002) found that creative artists themselves differ in their definition of what creativity is, with some artists putting more emphasis on the originality or unusualness of creative work, while others find functionality or usefulness more important. However, the general consensus of all these definitions are that creativity includes an element of originality or unusualness and an element of novelty or creation.

Creativity is regularly assessed by the means of divergent thinking tests (e.g., Torrance, 1974; Torrance, 1981; Wallach & Kogan, 1965). These divergent thinking tests include measures of how many different ideas are generated (fluency), and how original the ideas are (originality). It has been found that people who can think of many different ideas are also more likely to think of more original ideas (e.g., Clark & Mirels, 1970; Torrance, 2008). This suggests that the generation of ideas and producing novel and original (i.e., creative) ideas go hand in hand. Therefore, divergent thinking is argued to be an important cognitive skill in the process of individual learning to increase the variation of new ideas which in turn can lead to important changes to our knowledge repertoire.

In the next sections, past research on social learning and individual learning in children is discussed. Because of the importance of these learning mechanisms for the cultural evolution of our species, and in accordance with the learning theories described above, individual and social learning are argued to be observable from a young age.

1.1.3 Social Learning

Many studies have looked at how children learn from the behaviours of others through imitation (e.g., Bekkering, Wohlschläger, & Gattis, 2000; Nagell, Olguin, &

Tomasello, 1993; Simpson & Riggs, 2011; Wood, Kendal, & Flynn, 2013). Children reliably copy simple actions on objects from around 12 months (Barr, Dowden, & Hayne, 1996). They are not limited to vertical social transmission by imitating adults (e.g., Bekkering *et al*., 2000; Simpson & Riggs, 2011); they also imitate peers (e.g., Hanna & Meltzoff, 1993; Ryalls, Gul & Ryalls, 2000) allowing for horizontal social transmission.

Copying others' behaviours is a useful strategy to learn new behaviours because it provides children with possible options. Therefore not as much effort is required to find the best solution compared to a trial-and-error method (Rendell *et al*., 2010). Children who were able to copy the behaviour of others were shown to use tools more correctly (Nagell *et al.*, 1993), and were also more successful in finding a solution to a problem (e.g., retrieving a sticker out of a puzzle box; Wood *et al*., 2013) than children who did not get the chance to observe others' behaviour.

A side effect of children's reliance on social learning is that they tend to over-imitate others' behaviour; that is they copy behaviour that is not necessarily functional to reach the goal (e.g., Flynn, 2008; McGuigan, Whiten, Flynn & Horner, 2007; Nagell *et al*., 1993; Whiten, Custance, Gomez, Teixidor, & Bard, 1996). Although some studies have suggested that children over-imitate because they have poor physical understanding about the task and do not realize that the irrelevant actions are actually unnecessary (e.g., Lyons, Young & Keil, 2007); other studies have argued against this possibility (e.g., Simpson & Riggs, 2011) or suggest a more social explanation (e.g., Carpenter, 2006; Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Meltzoff, 2007). For example, Hilbrink *et al.* (2013) found that children who were more extraverted were also more likely to imitate unnecessary actions. Their explanation for this was that children who are more extraverted have a higher desire to interact with other people. A greater interest in the interpersonal aspects of the interaction with the experimenter could explain the higher faithful imitation of these children. This suggests that social learning might not only serve a functional role in reducing the time required to learn new things, but that it might also serve a social function.

Studies on selective imitation have shown that children do not just copy all behaviours. Children selectively copy others more closely when they have a goal to affiliate with the model (Over & Carpenter, 2009) or when the model is more socially responsive (i.e., a model who performed actions was in the same room vs. shown on a television screen; Nielsen, Simcock, & Jenkins, 2008). Furthermore, children are more likely to imitate jokes (Hoicka & Akhtar, 2011) and unusual novel actions when an adult is native-speaking compared to foreign-speaking adults (Buttelmann, Zmyj, Daum, & Carpenter, 2012). These studies suggest that children do not just copy any behaviour but take into account the characteristics of the model in their assessment as to whether to copy the behaviour or not.

1.1.4 Individual Learning

Children are generally interested in novelty. They spend more time looking at novel stimuli than at familiar stimuli (e.g., Kirkham, Slemmer, & Johnson, 2002), which forms the basis of most experimental work on infants' ability to detect differences in stimuli (e.g., Kirkham *et al.*, 2002; Leinbach & Fagot, 1993; Woodward, Sommerville, & Guajardo, 2001). As early as 4 months of age, infants understand basic properties of objects like solidity (e.g., Baillargeon, Needham, & DeVos, 1992) and continuity (e.g., Spelke, Kestenbaum, Simons, & Wein, 1995), and around 12 months they distinguish between inanimate and animate objects (e.g., Woodward, 1998). Children's understanding of object properties is likely formed by observing other people handle objects (e.g., a ball bounces when it is dropped on the floor from a certain height), or by handling the object themselves (e.g., when I bang this object on the table it makes noise).

1.1.4.1 Object exploration

Individual learning through the exploration of objects starts in the first year of life (e.g., Belsky & Most, 1981; Bourgeois, Khawar, Neal, & Lockman, 2005; Lockman, 2000; Lockman & McHale, 1989; Striano & Bushnell, 2005). When children are given an object, they, for example, put it in their mouth, move it around, or squeeze it. When handling an object, a child explores what the possibilities of an object are and what different features it contains. Gibson (1979) called this finding the *affordances* of an object and described this term as follows: “The affordances of the environment are what it *offers* the animal, what it provides or furnishes, either for good or for ill” (p. 127). Affordances are not objective, universal features of an object, but must be seen in relation to who is handling the object. Water for example is a liquid that affords drinking or washing for a human, but for certain insects this same water affords a support to stand on (e.g., water strider; Ward, 1992). In this way, the affordance of water to provide support is relative to the insect but not to the human.

Bourgeois and colleagues (2005) found that 6-month-olds already explore the affordances of different objects. Infants were found to take into account both the material of the object and the type of surface when performing actions. For example, they banged a hard cube on a rigid or discontinuous surface more often than on a flexible or liquid surface. Furthermore, infants banged less frequently with the soft cube compared to the hard cube, indicating infants’ understanding that hard objects afford to make noise while soft objects do so less. By exploring the different affordances of an object, children increase their knowledge of the possibilities of that object. This in turn gives them more options in how to use the object.

Studies on children’s ability to detect affordances in objects (e.g., Bourgeois et al., 2005; Lockman, 2000) show us that children do explore objects and differentiate their uses. However these studies do not provide us with any information about the range of options children can find for different objects nor does it provide us with possible individual differences between children’s ability to find multiple options. For example, Bourgeois and colleagues provided children with three types of cubes (hard, soft and mixed) and different surfaces, but they only reported specific actions that allowed them to differentiate between the different blocks and surfaces. Lockman and McHale (1989) have previously mentioned how most studies on children’s object exploration have focused on children’s ability to detect differences, and not necessarily on how they explore the specific objects.

This thesis aimed to fill this gap by investigating children’s ability to generate multiple actions with novel objects. Children were given a box to play with (the Unusual Box) that contained different features (e.g., stairs, rings, ledges) in combination with novel objects that in shape, texture and size were very different from each other. This allowed children to generate a large number of possible actions. Individual differences and age-related changes in children’s ability to generate multiple actions were assessed.

1.1.4.2 Generation of iconic gestures as a means of communication

Children are able to communicate their needs to others as soon as they are born. Through crying they tell others that they require food, sleep, comfort, and so on (Lummaa, Vuorisalo, Barr, & Lehtonen, 1998). Infants start communicating through speech towards the end of the first year (Benedict, 1979), which gives them more freedom to express their specific needs. For example, while a cry can stand for different needs (Müller, Hollien, & Murry, 1974) words give a more reliable clue of what the child desires (e.g., saying the word ‘food’ when wanting to be fed). Children learn to speak through social learning, by mapping words to specific objects (e.g., Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006). However, children are also shown to be able to generate their own object labels in a joking setting (Hoicka & Akhtar, 2011). Similarly, deaf children who use sign language instead of verbal language have been shown to create their own gestures (Mylander & Goldin-Meadow, 1991).

Gestures are used as a means of communication from an early age. An interesting example is the development of a communication system in deaf children, called homesign (Morford & Goldin-Meadow, 1997). Homesign is observed in deaf children who are born to hearing parents, but the parents have chosen not to expose them to sign language. These children are shown to create stable gesture vocabularies including nouns and verbs (Goldin-Meadow, Butcher, Mylander, & Dodge, 1994). Similar creations of gestures have been observed in pre-verbal hearing children. For example, Acredolo and Goodwyn (2000) described how Acredolo’s daughter Kate came up with different ‘baby signs’ to represent objects before she could talk (e.g., sniffing gesture for flower).

Iconic gestures are a type of gesture that symbolically represent objects, events, desires and conditions (Acredolo & Goodwyn, 1988), and are similar irrespective of context (Capone & McGregor, 2004). For example, the iconic gesture of a cup (or drinking) is holding your hand in a semi-circle and moving it towards your mouth while tilting the wrist. Children produce iconic gestures from around 14 months (Acredolo & Goodwyn, 1988), which are used in particular to clarify aspects that are harder to verbalize (Campana, Silverman, Tanenhaus, & Benetto, 2004). This suggests that speech is typically the first choice for communication, while gestures are used in addition to speech.

Although children show the ability to produce iconic gestures from early on, it is not clear whether children really generate these gestures by themselves. The studies which describe children's production of gestures do not provide a clear picture on how children developed the use of these gestures. For example, Kate's production of the baby sign for flower by sniffing could be the action that she associated with seeing a flower, perhaps because her mother used to perform this behaviour when receiving flowers. Therefore, Kate's production of the sniffing behaviour does not immediately suggest that she produced this gesture in order to communicate, nor whether the behaviour is more than an automatic response associated with seeing a flower.

Another downside of previous studies is that they cannot confirm whether children understand that the iconic gesture represents another object. For example, one possibility could be that children associate certain movements (e.g., holding your hand as a semi-circle and moving it towards your mouth while tilting the wrist) with the accompanied response by adults (receiving a cup containing a beverage). This association does not require children to understand that adults interpret the child's movement as representing the use of a cup and therefore provide the child with a beverage. On the other hand, experimental studies that investigated children's understanding of the representational nature of iconic gestures (e.g., Namy, Campbell, & Tomasello, 2004; Tolar, Lederberg, Gokhale, and Tomasello, 2008) only assessed children's responses to iconic gestures produced by an experimenter, and did not look at children's own production of these gestures. Therefore, they cannot provide us with information as to whether children use this representational information when they generate their own iconic gestures. Our aim was to investigate whether children are indeed able to generate iconic gestures they have not seen produced before; whether they generate these gestures in order to communicate with others; and whether they take into account the representational nature of iconic gestures.

1.1.4.3 Generating object substitution actions during pretend play

Pretend play relates to any play behaviour in which (1) inanimate objects are treated as animate (e.g., petting a stuffed toy animal), (2) everyday activities are performed in the absence of the necessary materials (e.g., drinking from an empty cup), (3) a child preforms actions usually done by someone else (e.g., vacuum cleaning), (4) activities are not carried out to their usual outcome (e.g., writing with a pen but not leaving a mark on the paper), or (5) one object is substituted for another (e.g., using a banana as a phone; McCune-Nicolich, 1981). Before their first birthday, children are often introduced to pretend play by their parents. Crawley and Sherrod (1984) found that although none of the children performed pretend actions at 7 months, 33% of the mothers modelled pretend play actions to their children. This further increased to 75% of the mothers showing pretend play to their children at 13 months, by which time 42% of children also performed pretend actions. This suggests that children initially observe pretend play behaviour before they start using this in their own play.

Children typically start pretending during their first year of life (McCune-Nicolich, 1981; Vig, 2007). At first, children perform pretend actions with the actual object (e.g., drinking from an empty cup) but during the third year of life children become more flexible and show pretending in which they use an object as if it is something else (i.e., object substitution). Object substitution requires a child to temporarily inhibit the original use of the object, while performing the action of the pretend object instead.

The options of pretending using object substitution are endless. This basically means that when using object substitution a child can pretend an object to be whatever s/he wants it to be. However, until 3 years children still rely on the substituted object being similar to the pretend object (e.g., pretending a tissue is a blanket; Elder & Pederson, 1978). This means that children still rely on physical similarities between the object they are holding and the pretend identity they are giving to the object. This suggests that children's ability to mentally represent one object as something completely different is still low.

Current literature cannot shed light on children's representational abilities when using object substitution. Studies which investigated children's generation of object substitution actions often first performed the pretend action themselves (e.g., Harris & Kavanaugh, 1993; Rakoczy, Tomasello, & Striano, 2004) therefore they cannot rule out that children simply imitated the pretend action. On the other hand, studies that did not model any actions gave specific prompts to indicate what the child should do (e.g., "show what Teddy does with a spoon", Harris & Kavanaugh, 1993). Therefore, children might have just performed the action they were told to do, and we do not know for sure whether children would indeed be able to create these pretend actions without any help from an adult. Our aim was to investigate whether children are indeed able to generate object substitution actions without having seen the action modelled beforehand or having been given specific prompts to perform a certain action; and whether they take into account the representational nature of object substitution actions.

1.1.4.4 Focus of this thesis

Although individual learning has been argued to be of similar importance as social learning (Mesoudi *et al*., 2004), most research has focused on social learning and seem to diminish the role of individual learning by arguing it is not as efficient (e.g., Barr, Dowden, & Hayne, 1996; Ladyshewsky, 2002), that children prefer copying over using their own individual experiences (e.g., Jaswal & Markman, 2007), or they discuss it in the light of social learning (i.e., emulation, in which children imitate the goal of an action but generate their own way of reaching the same goal; e.g., Horner & Whiten, 2005). Studies that do investigate individual learning mainly focus on infant's learning experiences when they are very young (e.g., Belsky & Most, 1981; Bourgeois *et al.*, 2005), or investigate specific skills in adults that contribute to their ability to solve problems more effectively (e.g., brainstorming as goal to generate more creative ideas; Parnes & Meadow, 1959).

A more general investigation of children's ability to use individual learning in order to generate new ideas seems to be lacking. To fill this gap, this thesis focused on children's ability to generate novel actions. The rationale for the focus on the generation of novel actions was that it allowed us to measure individual learning directly by analysing the behaviour of children. Direct behavioural measurements were chosen over indirect measures of individual learning through speech, since young children have a limited vocabulary and therefore it is hard to reliably asses their cognitive processes through speech. Three different types of generating novel actions – generating actions with novel objects, generating iconic gestures, and generating pretend actions – were chosen to offer a varied investigation of children's ability to generate novel actions. First, we investigated children's individual learning through the generation of actions with of novel objects. The design of this study was open, i.e., no specific instructions were given, which allowed children to display their natural curiosity to explore. Novel objects were used to observe children's first encounter with an object and assess how they go about exploring the different functions an object could have. Second, we investigated children's ability to use individual learning in a representational way, i.e., generate actions that represent another object. In one study we investigated children's ability to use representational (iconic) gestures in a communicative setting, while in another study we used a pretend play setting to investigate children's ability to represent one object for another. For both representation studies familiar objects were used. However, in the selection of familiar objects and object combinations we made sure to select combinations that decreased the likelihood that children had seen others generate these actions before.

1.1.5 Overarching research aims

The overall aim of this thesis was to gain information about children's ability to generate actions without getting input from others. This information could give us insight into which skills are important for individual learning in children, and it might give us ideas for stimulating individual learning. Given that individual learning is important to create variation in cultural traits, which in turn is important for us to adapt to changes in the environment, the broader impact of this thesis is to gain information on what skills children already possess that might help them to become good creators of new ideas.

For all three types of generating novel actions, children's flexibility is thought to be important for their ability to generate actions. When generating multiple actions with novel objects, children require a certain curiosity to search beyond the first action performed and explore the different uses of the object. Regarding generating iconic gestures in order to communicate, verbal requests or pointing to the desired object are more common ways of communicating in everyday life (Özçalişkan & Goldin-Meadow, 2011). However, in our study (see below for a more detailed description) these means of communication were not an option. Therefore, children required a certain flexibility to switch from their normal means of communication to an alternative way, namely using iconic gestures. Finally, when generating object substitution actions children needed to be flexible in thinking about the ways an object can be used. During object substitution, the original action with the object has to be inhibited and a different action that one normally does with another object has to be performed instead. Therefore, children who are flexible in the use of an object are thought to be better at object substitution than children who find it hard to inhibit the original action with the object.

1.2 Thesis Outline

This thesis investigates children's ability to generate actions in three different areas: 1) generating multiple actions with novel objects, 2) generating iconic gestures in order to communicate, and 3) generating pretend actions using object substitution.

Chapter 2 sought to investigate children's ability to generate multiple actions with novel objects. This ability is thought to be influenced by children's divergent thinking skills. Divergent thinking relates to thinking beyond what is available at the moment and to search for new alternatives. Children with high divergent thinking skills were expected to generate more actions with novel objects than children with low divergent thinking skills. In order to investigate this hypothesis, 3- and 4-year-olds were tested on three existing measures of divergent thinking in combination with a new test that assessed children's ability to generate multiple actions with novel objects, the Unusual Box Test. Divergent thinking was hypothesized to be the main underlying factor causing individual differences in novel object exploration, therefore high correlations between divergent thinking scores on the existing measures of divergent thinking on the one hand, and the number of actions that children generated with the novel objects on the other hand were expected.

A second aim of Chapter 2 was to investigate whether the Unusual Box test was applicable to children younger than 3 years. Currently available divergent thinking tests allow us to assess children's divergent thinking skills as young as 3 years. The requirement to respond verbally (e.g., Wallach & Kogan, 1965), and understand the task instructions (e.g., TCAM; Torrance, 1981) in currently available divergent thinking tests impedes the use of these tests in a younger age group. The Unusual Box test sought to evade these requirements by 1) not demanding any verbal responses, and 2) limiting task instructions by just prompting children to play with the novel toys. In Study 2 of Chapter 2 the test-retest reliability of the Unusual Box Test was assessed in a sample of 2-year-olds. High correlations between the number of actions generated in the first assessment and a second assessment two weeks later, would indicate that children’s divergent thinking scores are stable over a short period of time. Furthermore, the absence of a floor effect in children’s scores, which meant that they produced multiple actions with the novel objects, and individual differences were indicators that the Unusual Box Test was a reliable measure of divergent thinking in children younger than 3.

The experiment in Chapter 3 assessed children’s generation of iconic gestures by asking them to request an object with a sticker attached to it. It was impossible to request this object through speech, as the experimenter who had the object was wearing headphones and therefore could not hear anything the child was saying. The child could also not obtain the object by pointing, since there was a second object present that was placed immediately next to the target object. Therefore the experimenter could not distinguish which of the two objects the child requested when pointing to the object. The only other alternative was to make an iconic gesture that represented the object. If the iconic gesture was clear enough to distinguish between the two objects, the experimenter would understand which object the child requested and in return would give the child the object with the sticker. This experimental design allowed us to assess 1) whether children are able to generate iconic gestures in order to communicate, and 2) whether children understand the representational nature of iconic gestures, and use this in their own generation of iconic gestures. All data in Chapter 3 was collected during a two-month research visit at Max Planck Institute of Psycholinguistics in the Netherlands, in collaboration with Dr Ulf Liszkowski.

Finally, children's ability to generate pretend actions using object substitution is described in Chapter 4. An important feature of object substitution is that the actions performed during pretence are technically wrong actions. For example, when pretending to use a banana as if it is a phone, you are not using the banana for its original use; that is pealing the banana and eating it. Instead you are holding the banana against your ear and talking into it. The crucial difference between this pretend action and making a mistake, when you actually intended to eat the banana, is that during the pretend action it was the pretender's intention to do it 'wrong'. Study 1 in Chapter 4 aimed to investigate children's ability to generate pretend actions using object substitution, and whether they distinguished between the intentions of an experimenter when she was pretending or making a mistake.

Furthermore, in Study 2 of Chapter 4 we further investigated two factors that were hypothesized to influence children's ability to generate pretend actions using object substitution. First, divergent thinking skills were expected to be positively correlated to children's ability to use object substitution. The hypothesis was that children who were flexible in their use of objects (high divergent thinking) would also be better in pretending that objects were something else. Second, children's inhibitory control was expected to impact children's ability to use object substitution. Children with low inhibitory control find it difficult to inhibit an initial response and therefore were hypothesized to be more likely to do the original action with an object, rather than use object substitution to pretend it is something else. We investigated the influence of divergent thinking and inhibitory control on children's generation of object substitution, both in an experimental and free play setting.

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Chapter 2

Individual Differences and Age-related Changes in Divergent Thinking in Toddlers and Preschoolers

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Abstract

Divergent thinking shows the ability to search for new ideas, which is an important factor contributing to innovation, problem solving, and cultural evolution. Current divergent thinking tests allow us to study children's divergent thinking from 3 years on. This paper presents the first measure of divergent thinking that can be used with children as young as 2 years. The Unusual Box test is a non-verbal and non-imitative test in which children play individually with a novel toy and novel objects. Divergent thinking is scored as the number of different actions performed. Study 1 found that the Unusual Box test is a valid measure of divergent thinking as it correlates with standard measures of divergent thinking in 3- and 4-year-olds. Study 2 indicates that the test can be used with 2-year-olds, as it shows high test-retest reliability, demonstrating that 2-year-olds can think divergently. In both studies individual differences and age-related changes were found, indicating that some children are better at divergent thinking than others which might make them better innovators in the future, and that children's divergent thinking increases with age. This test will allow us to gain insight into the early emergence of divergent thinking, which is crucial for increasing our understanding of cultural evolution and innovation in society.

Keywords: Divergent thinking; Creativity; Innovation; Cultural Evolution; Toddlers

2.1 Introduction

Research on innovation and creativity has received increasing attention over the past few years (e.g., Becheikh, Landry, & Amara, 2006; Kaufman, Butt, Kaufman, & Colbert-White, 2011; Van der Panne, Van Beers, & KleinKnecht, 2003). Innovation can be defined as the process by which new ideas are introduced to a group or society which results in increased performance of that group or society (Rogers, 1998). This definition highlights two important aspects of innovation: it must be novel, and it must be useful or beneficial. In this paper we will focus on the novelty aspect of innovation. To come up with novel ideas requires the ability to think beyond what is available at the moment and search for new alternatives. This ability to search for new ideas is termed divergent thinking (Guilford, 1959). Although there is ample research about divergent thinking in adults and older children (for a review see Runco, 1992), we do not yet know how this ability emerges. This paper will determine whether we can measure divergent thinking in children as young as 2 years.

One reason that divergent thinking is important is that it is linked to problem solving. Guildford (1975) went as far as to state that “all genuine problem solving requires at least a minimum of creative thinking” (p. 107). Individuals who can think of more different answers to a question are more likely to come up with original, novel ideas (e.g., Kim, 2006). Brainstorming is a form of divergent thinking where someone produces as many different solutions to a problem as possible without evaluating the quality of each solution. Brainstorming is found to increase the number of “good” ideas produced during problem solving (Meadow, Parnes, & Reese, 1959; Parnes & Meadow, 1959). McAdam and McClelland (2002) emphasize the importance of the generation of ideas in the process of innovation. We suggest therefore that divergent thinking is an important ability as it could lead to an increase of good ideas and hence help drive innovation.

Divergent thinking may also be an important aspect of cultural evolution. According to Mesoudi, Whiten, and Laland (2004) cultural evolution is dependent on competition, inheritance, and variation. One requirement of cultural evolution is that multiple traits (e.g., artefacts, ideas) are competing for the same purpose. Cultural traits can only live on if they are inherited, or socially transmitted, towards other people. A widely studied form of social transmission is imitation (e.g., Caldwell & Millen, 2008; Horner, Whiten, Flynn, & de Waal, 2006; for an overview of studies with adults: Mesoudi & Whiten, 2008; and children: Flynn, 2008). A large body of research shows that social transmission through imitation occurs as early as 1 year (e.g., Carpenter, Nagell, & Tomasello, 1998; Hanna & Meltzoff, 1993; Ryalls, Gul, & Ryalls, 2000). Finally, for cultural evolution to take place variation of cultural traits is required and these cultural traits should be different from existing traits. These variations of traits can be completely new ideas or behaviours, or modifications of existing traits, and so are in essence innovations. Although it is known that infants explore objects as early as 6 months (Bourgeois, Khawar, Neal, & Lockman, 2005), it is not yet known whether young children explore objects divergently. To have a full picture of how we engage in cultural evolution, we must determine how variation, or divergent thinking, emerges.

As divergent thinking is an important factor contributing to innovation, problem solving, and cultural evolution, it is important to understand how this ability emerges early on. However there are no tools to discover when young children begin to think divergently, nor how this process comes about. Several tests of divergent thinking exist which can be reliably used with adults and children of at least 4 or 5 years of age, including the Wallach and Kogan tests of creativity (Wallach & Kogan, 1965) and the Torrance Test of Creative Thinking (TTCT, Torrance, 1974). These tests involve giving as many different responses as possible to questions such as, "How many things are round?" However these tests are not suitable for younger children given the verbal task demands. The Thinking Creatively in Action and Movement test (TCAM; Torrance, 1981) was created to resolve this problem. In this test children perform as many actions as possible for items such as moving between two lines (e.g., dancing, hopping). Although the TCAM is a good alternative to measure divergent thinking in children as young as 3 years, there are three important downsides to using it with children younger than 3 years. First, these measurements require a level of verbal understanding that might not be appropriate for younger children. For example, in three out of four subtests the experimenter asks the child, "Now you do something different". However, the understanding of abstract concepts like same and different requires analogical thinking which is limited until 3 years (Goswami, 1992). Additionally, most 2-year-olds do not yet produce the word "same", and the word "different" is not in the MacArthur-Bates Communicative Development Inventory suggesting it may not be a commonly understood word (Dale & Fenson, 1996). Second, all subtests of the TCAM start with two examples, which the children imitate to understand the goal of the game. When the authors piloted the TCAM on 2-year-olds, children continued imitating rather than showing new actions. This is in line with research that children over-imitate at this age (e.g., Flynn, 2008). It may also be difficult for toddlers to suppress the modelled actions due to inhibitory control demands (e.g., Gerstadt, Hong, & Diamond, 1994; Simpson & Riggs, 2011). Third, the divergent thinking tests that are currently available (TCAM, 1981; TTCT, 1974; Wallach & Kogan, 1965) mostly investigate novel uses for existing objects (e.g., novel uses of a paper cup; Torrance, 1981). Children under 3 years may find it difficult to use familiar objects in novel ways due to inhibitory control demands. In order to avoid these task demands a new divergent thinking test is proposed. No specific questions are asked of the child, other than to play with some exciting toys for a period of time.

The goal of the current studies was to assess the validity and test-retest reliability of a new measure of divergent thinking, called the Unusual Box test. The Unusual Box test relies on children's natural curiosity and exploratory behaviour (e.g., Bourgeois et al., 2005, Fontenelle, Kahrs, Neal, Newton, & Lockman, 2007), in the sense that children are not told in advance to do as many different actions as possible. In this test the child is presented with a box with several different features (e.g., round hole, strings, stairs). The child is encouraged to play with the box, together with five different objects that are unfamiliar to the child. In the first study the Unusual Box test was compared to three other divergent thinking tests in 3- and 4-year-olds: the TCAM and the Instances and Pattern Meanings subtests of the Wallach-Kogan tests of creativity. It was expected that the divergent thinking scores on the Unusual Box test would be positively correlated to the scores of the existing divergent thinking tests, which would suggest that the Unusual Box test does in fact capture divergent thinking. The second study investigated whether the Unusual Box test was a suitable and reliable measure for 2-year-olds. High test-retest reliability would suggest that the measure is stable over time. Possible age differences in divergent thinking were also investigated by combining the data of both studies.

2.2 Study 1

Study 1 sought to investigate the validity of the Unusual Box test by comparing the scores of 3- and 4-year-olds on the Unusual Box test to their scores on three existing divergent thinking tests: the Instances and Pattern Meanings subtests of the Wallach-Kogan tests of creativity (Wallach & Kogan, 1965), and the TCAM (Torrance, 1981). These tests were chosen because they all have different ways of assessing divergent thinking. The Instances subtest asks children verbal questions, and children must give a verbal answer. For the Pattern Meaning subtest, the experimenter shows a line drawing, and children must respond with a verbal answer. In the TCAM, the experimenter demonstrates both verbally and behaviourally (showing examples in movement), and the child can respond both verbally and behaviourally.

2.2.1 Method

2.2.1.1 Participants

Twenty-four children participated (13 males, *mean age* = 45 months, 27 days; *range* = 37 months, 1 day – 57 months, 20 days; *SD* = 5 months, 21 days). An additional eight children were excluded due to failure to engage (6) or to complete one or more tasks (2). Children were recruited from nurseries and playgroups. All children were British.

2.2.1.2 Design

A within-subjects design was used. All children were tested on the Unusual Box test, Instances, Pattern Meanings, and the TCAM across three separate occasions (average number of days between assessment 1 and 3: 35 days, *range* 0-89 days, *SD* = 25 days). The order in which the tests were run was counterbalanced between children, although Instances and Pattern Meanings were always run together. For the Unusual Box test, the order of objects given to children was counterbalanced.

2.2.1.3 Measures

Unusual Box test

The apparatus consisted of a wooden box (34x18x14cm) with an open top. It contained the following features (see Figure 1): (1) Ledges; three small blocks attached to an external wall of the box, and one shelf-like block upon which objects could be placed. (2) Strings; 21 aligned tie-wrap straps of various colours. A wire was guided through the opening of the tie-wrap straps so they could hang down on an external wall of the box. The wire had two knots on each side and was attached to the side of the box. The strings could be moved up and down, as well as be bent. (3) Rings; seven closed tie-wraps in different sizes and colours, attached to an external wall of the box. (4) Round hole; a hole (5.7cm in diameter) cut into the short side of the box opposite the strings. (5) Rectangular room; a space of 10x5x8cm that could be reached via the round hole or the top of the box. (6) Stairs; two steps and a small edge on the top, covering two-thirds of the inside of the box. The stairs could be reached from the top of the box. The box was placed on a black plastic turntable (25cm in diameter), to make sure that each side of the box could be easily reached by the child. Furthermore, five objects were used in the Unusual Box test, which were novel to the participants (see Figure 1): a spiral-shaped egg holder, spatula, feather roller, Kong rubber toy and hook. A digital video camcorder (SONY Handycam) was placed on a tripod on the left-hand side behind the child (approximately 1 meter away). The camera was angled down from approximately 1 meter high, in order to film the actions that the child performed in front of, as well as inside, the box.

Figure 1: The Unusual Box (containing the following features: ledges, strings, rings, round hole, rectangular room, and stairs); and the novel objects used in the Unusual Box test (from left to right: egg holder, spatula, feather roller, Kong rubber toy, and hook).

At the start of the Unusual Box test the experimenter explained to the child that they would play a fun game. She put the turntable on the table, and placed the Unusual Box on top of it. The experimenter highlighted each part of the box in the following order: ledges (named 'blocks'), strings, rings, round hole, rectangular room (named 'little room'), and stairs. The experimenter turned the box while explaining so that the specific features were directly in front of the child. The child was given a chance to turn the box as well. Next, the child was told that he or she could play with the box together with another toy, until the experimenter instructed that he or she should stop. The child was then given one out of five objects. He or she was given 90 seconds to play with each object, after which the object was replaced by a new one. When the child asked for clarification of the use of the object, the experimenter responded by saying, "I don't know, you have a look and see what you can do." At the end of the test, the child was given a sticker as a reward for participation.

The behaviour of the child was coded for all five trials. Each trial started the moment that the child took the novel object from the experimenter, and lasted for 90 seconds. Actions were recorded on two features: what action was performed (e.g., jump, hit, place; for full list see Appendix A, p. 167) and what part of the box was used during the action (e.g., ledges, round hole, see Appendix A, p. 167). One action might be rolling one of the objects on the stairs. Actions performed on the box with the hands instead of an object were counted as an action. Actions that were performed without using the box, with the object only, were also counted. Performance of the same action with different objects was counted as one action. Inter-rater agreement was calculated on the individual actions children performed. For each possible action (180 actions in total) it was assessed whether either or both raters had coded the action as being generated or not. Inter-rater agreement for 20% of the videos was good (*Cohen's kappa* = 0.81).

For each child two different types of scores were calculated: a fluency score and an originality score. The fluency score consisted of the number of different actions that the child performed for all trials combined (5 x 90 seconds). In addition to analyzing children's number of responses (fluency), the quality of their responses was analyzed by calculating originality scores. Each separate action that a child performed was given an originality score based on an originality index. Actions that were performed by fewer than 5% of the children got a score of 3; actions performed by fewer than 20% of the children got a score of 2; actions performed by 20-50% of the children got a score of 1; and actions performed by more than 50% of the children got a score of 0 (note that in order to get a sufficient distribution of originality scores it was necessary to combine the actions performed in Studies 1 and 2; $N = 40$). Next, a total originality score was calculated for each child by adding up the originality scores of all the actions that he or she had performed.

Instances

Three out of four items of the original Instances subtest (Wallach & Kogan, 1965) were used. The items were presented in the following order: “Name all round things you can think of”, “Name all the things you can think of that will make noise”, and “Name all the things you can think of that move on wheels”. The item “Name all the square things you can think of” was removed from the test because during pilot testing 3-year-olds had trouble understanding what square meant, and responded with random answers.

The child was asked to name as many things that could encompass a statement as they could think of. There was no time limit for children to respond. If the child gave no more responses and the experimenter had asked twice whether he or she could give another answer to the question, the experimenter continued with a new question. A voice recorder (Olympus) was used to record the children’s answers.

The responses of the child were coded for fluency and originality. Fluency scores were calculated by counting the number of different correct answers that a child gave. For example, when asked to “name all the round things you can think of” a circle was coded as a correct answer, while a knife was coded as incorrect. A total score was calculated by adding up the number of correct answers on all items. Originality scores were computed by adding up the total number of unique correct answers given, compared to the other children in the sample, following Wallach and Kogan (1965).

Pattern Meanings

The Pattern Meanings subtest included a series of line drawings. Only the first four out of nine items mentioned by Wallach and Kogan (1965) were used (See

Appendix B, p.169). The other items were excluded because during pilot testing 3-year-olds did not pay attention for more than four items and did not want to continue, or kept on answering “I don’t know”. A voice recorder (Olympus) was used to record the child’s answers.

The child was presented with one of the four drawing each time and he or she had to describe what different things the drawings could be. There was no time limit for children to respond. If the child gave no more responses and the experimenter had asked twice whether he or she could think of something else that it could be the child was presented with a new picture. The responses of the child were coded for fluency and originality, in the same way as in the Instances subtest.

TCAM

All four subtests of the TCAM (Torrance, 1981) were run. First, the subtest, “What might it be?” was run, in which the child had to think of as many uses for a paper cup as possible. Five white polystyrene cups were used. Two examples, using the cup as a hat and driving it around like a car, were given before the child could have a turn. In the second subtest, “How many ways?” two lines were created on the floor (approximately 1.5 meters apart) using duct-tape. The child was asked to move between two lines in as many ways as possible. Walking and crawling were given as examples. In the third subtest called, “Can you move like?” the child responded to six statements, e.g., “Can you move like a tree in the wind?” (for all statements, see Torrance, 1981). As this subtest was a task of pretending, and was only scored for imagination and not necessarily divergent thinking, this subtest was not analysed. For the last subtest, “What other ways?” the same polystyrene cups from the first subtest were used and a small garbage bin. The child was asked to put cups into a bin in as many different ways as possible. Two examples given were putting the cup on the palm of the hand and pushing it in with the other hand and throwing the cup in the bin while standing a meter away from the bin. The child's actions were recorded with two digital video camcorders (SONY Handycam) on tripods. The cameras were placed in two corners of the room, such that all the child's movements were visible by at least one of the cameras. There was no time limit on children's responses in any subtest.

The behaviour of the child was coded for fluency and originality. Fluency scores were calculated by counting the number of different correct answers. For the "What might it be?" subtest, correct answers included actions that involved placing the cup in unusual places or building something out of several cups. The "How many ways?" subtest was coded for the number of times a child moved in a different way. For the "What other ways" subtest, correct answers included dropping the cup into the bin from one of the child's body parts (e.g., knee drop, arm drop, head drop), making specific movements with the cup (e.g., spin) before throwing it into the bin or putting the cup into the bin accompanied by something else (e.g., skip to the bin, then throw the cup in the bin). Lists of some possible answers for all three subtests are given by Torrance (1981).

Originality scores were calculated following the manual provided with the TCAM (Torrance, 1981). Each response in the manual corresponds with an originality score. This score was based "primarily upon the statistical infrequency of the response in a normative sample of five hundred children" (Torrance, 1981, p. 15). Each separate response was given an originality score between 0 and 4. All scores were added up to provide a total originality score.

2.2.2 Results

2.2.2.1 Validity of fluency scores

Table 1 shows the descriptive statistics of the fluency scores for each test. Children performed on average 24.0 actions on the Unusual Box test, with a range of 8 to 34 actions. No effects of gender were found in any analyses. Age was positively correlated to the Instances (Pearson's $r = .47$, p = .022) and Pattern Meanings subtests (Pearson's $r = .40$, p = .05). Therefore further analyses were corrected for age.

The correlations between the test scores are also given in Table 1. The Unusual Box test was positively correlated to the Instances subtest and the TCAM, but not to the Pattern Meanings subtest. In fact, the Pattern Meanings subtest scores were not significantly correlated to any of the other tests, including the Instances subtest.

Table 1: Descriptive Statistics and Correlations of Fluency Scores among all Divergent Thinking Tests in Study 1.

			Correlations			
	Mean	Range	Age	1^a	2^a	3^a
1. Unusual Box test	24.00 (6.5)	8 – 34	.18			
2. Instances	8.33 (4.1)	2 – 18	.49*	.49*		
3. Pattern Meanings	5.83 (2.0)	3 – 10	.44*	.34	.22	
4. TCAM	91.58 (11.2)	71 – 114	-.32	.60**	.60**	.02

Note: N = 24. Standard deviations are given in parentheses.

[a] Partial correlations, corrected for age.

*p < .05. **p < .01

2.2.2.2 Validity of originality scores

Table 2 shows the descriptive statistics of the originality scores for each test. No differences in gender or age were found. The originality scores of the Unusual Box test and the Pattern Meanings subtests were positively correlated. The positive correlations between the originality scores of the Unusual Box test and both the Instances subtest and TCAM were marginally significant ($p = .06$ and $p = .07$ respectively). However, for every test the originality and fluency scores were correlated (Unusual Box: *Pearson's r* = .877, $p < .001$; Instances: *Pearson's r* = .839, $p < .001$; Pattern Meanings: *Pearson's r* = .578, $p = .003$; TCAM: *Pearson's r* = .688, $p < .001$). Therefore ratio scores were calculated for all measures by dividing originality scores by fluency scores. None of the ratio originality scores correlated with each other (all $p > .180$). This indicates that any correlations that existed between the originality scores were due to correlations between the fluency scores.

Table 2: Descriptive Statistics and Correlations of Originality Scores among all Divergent Thinking Tests in Study 1.

			Correlations			
	Mean	Range	1	2	3	4
1. Unusual Box	21.17 (9.0)	4 – 41				
2. Instances	2.96 (2.3)	0 – 8	.42*			
3. Pattern Meaning	2.04 (1.3)	0 – 5	.39†	.16		
4. TCAM	95.83 (9.6)	80 – 112	.38†	.22	.22	

Note: N = 24. Standard deviations are given in parentheses.

*p < .05, †p<.1

2.2.3 Discussion

The results show positive correlations between the fluency scores of the Unusual Box test, the Instances subtest, and the TCAM, with moderate to large effect sizes. This suggests that similar constructs are measured by these three tests. No significant correlation was found between the fluency scores of the Unusual Box test and Pattern Meanings. Interestingly however, many children could not think of more than one answer for each item on the Pattern Meanings subtest. This suggests a floor effect, and that the Pattern Meanings subtest might be too difficult for children as young as 3 years. Most studies using Pattern Meanings as a measure of divergent thinking tested participants of 5 years or older (e.g., Chan et al., 2001; Claridge & MacDonald, 2009; Runco, 1986). The results of this study suggest that 5 years might be an appropriate cut-off point for using the Pattern Meanings subtest. Given that the fluency scores on the Unusual Box test, Instances subtest and TCAM are all correlated with each other, the Unusual Box test appears to be a valid measure of divergent thinking.

Although the originality scores of the different tests were moderately correlated, this was due to the high correlations between originality and fluency scores on all tests. Previous studies have also reported similar correlations between fluency and originality scores (e.g., Clark & Mirels, 1970; Torrance, 2008). A possible explanation can be found in Mednick’s associative theory (Mednick, 1962), which states that original ideas are in principle remote. This means that people typically get original ideas after the more obvious ideas are depleted. It endorses the idea that high divergent thinking may lead to more novel and original ideas (e.g., Kim 2006), and confirms the importance of divergent thinking to enable cultural evolution, as it would produce more novel ideas.

2.3 Study 2

Study 2 sought to investigate the test-retest reliability of the Unusual Box test in 2-year-olds. If it is possible to use the Unusual Box test with children younger than 3 years, we might be able to investigate the emergence and development of divergent thinking. Furthermore, data from Studies 1 and 2 were combined to explore age differences in divergent thinking.

2.3.1 Method

2.3.1.1 Participants

Sixteen two-year-olds participated (7 males, *mean age* = 28 months, 5 days; *range* = 24 months, 12 days – 32 months, 29 days; *SD* = 2 months, 22 days). Two additional children were excluded from the study because they did not attend the second assessment (1) or failed to engage with the task (1). All children were British and of white ethnicity, and most parents had an education level of undergraduate degree or higher (6 Postgraduate degree, 6 Undergraduate, 2 High School, 2 unknown). Children were recruited from posters and parent-toddler groups as well as via online advertisements.

2.3.1.2 Materials

The materials used for the Unusual Box test were identical to those used in Study 1.

2.3.1.3 Design

A within-subjects design was used. All children completed the Unusual Box test twice, two weeks apart. Counterbalancing of objects was the same as in Study 1. For the second assessment, a different order of the objects was used.

2.3.1.4 Procedure

A short warm-up consisted of the child playing with a toy tractor and a stuffed toy gorilla. The procedure of the Unusual Box test was the same as in Study 1.

2.3.1.5 Coding

Coding for the Unusual Box test was the same as in Study 1.

2.3.2 Results

2.3.2.1 Test-retest reliability of fluency scores

The average score on the first assessment of the Unusual Box test was 19.3 actions (*SD* = 5.9, *range* = 10-32) and 20.5 on the second assessment (*SD* = 5.9, *range* = 12-36). No effects of gender were found in any analyses. No differences in scores were found between assessment 1 and assessment 2 (paired-sample $t = 1.106$, $p = 0.286$), indicating that children obtained similar scores on both assessments. A strong positive correlation was found between the scores of the two assessments (Pearson's $r = 0.738$, $p = .001$), indicating high test-retest reliability. The children performed on average 11.5 actions (*SD* = 4.0, *range* = 4-21) during the second assessment that were identical to the actions performed during the first assessment. In order to compare only the number of novel actions produced during both assessments the number of identical actions was subtracted from the total fluency scores of assessment 2. Compared to the first assessment children extended their use of the objects on the second assessment with on average 9.0 novel actions (*SD* = 3.2, *range* = 4-15). The fluency scores on assessment 1 were not significantly correlated to the number of novel actions performed on assessment 2 (Pearson's $r = .218$, $p = .418$). This suggests that although children performed novel actions during both assessments, children with high fluency scores on assessment 1 were not more likely to produce more novel actions in assessment 2. However, children with high fluency scores in assessment 2 were more likely to produce novel actions during that same assessment (Pearson's $r = .782$, $p < .001$). Furthermore, older 2-year-olds were more likely to produce novel actions on the second assessment than younger 2-year-olds (Pearson's $r = .592$, $p = .016$).

2.3.2.2 Test-retest reliability of originality scores

Congruent with Study 1, a strong positive correlation was found between originality scores and fluency scores on both assessments (assessment 1: $r = .889$, $p < .001$; assessment 2: $r = .954$, $p < .001$). Therefore for further analyses ratio originality scores were used.

On the first assessment children's average ratio originality score was 0.76 (*range* = 0.39-1.13, *SD* = 0.20) and 0.75 (*range* = 0.33-1.22, *SD* = 0.26) on the second assessment. No differences were found between the ratio originality scores on assessment 1 and assessment 2 (paired-sample $t = .037$, $p = .971$) and a positive correlation was found between the ratio originality scores of the two assessments (Pearson's $r = .577$, $p = .019$). This indicates that ratio originality scores are reliable over time. When only taking into account the novel actions in assessment 2 which the child did not produce in assessment 1, a positive correlation between the originality scores of assessment 1 and the originality scores of the novel actions in assessment 2 remained (Pearson's $r = 0.572$, $p = 0.021$). This indicates that children who produced original novel actions in the first assessment also produced more original novel actions in the second assessment.

2.3.2.3 Age differences in generating novel actions

The data of both studies were combined to investigate whether fluency and ratio originality scores on the Unusual Box test increased with age. For the 2-year-olds, only the actions from the first assessment were considered. Age was positively correlated with both fluency (*Pearson's* $r = .379$, $p = .016$) and ratio originality scores (*Pearson's* $r = .314$, $p = .049$).

2.3.3 Discussion

The results of Study 2 show a strong correlation between the two assessments of the Unusual Box test, indicating high test-retest reliability, both for fluency and ratio originality scores. Children’s divergent thinking skills are stable enough to yield similar findings two weeks later. When during the second assessment only novel actions (i.e., actions which the child did not produce during the first assessment) were taken into account, a positive relationship between the originality scores remained. Children who performed more original novel actions on the first assessment also produced more original novel actions two weeks later. However, there was no significant relationship between the number of novel actions on the two assessments. A possible reason for the non-significant correlation is the fact that the same objects were used on both occasions. Therefore, any actions that children produced in assessment 2 which they also produced in assessment 1 could not be counted as novel actions. The children in this sample produced between 4 and 21 actions which were identical on both occasions. The downside of calculating novel action production on assessment 2 by discounting all identical actions is that children with high fluency scores on assessment 1 have a higher chance of producing identical actions. Consequently, children who produced many novel actions in the first assessment had a lower chance of producing novel actions in the second assessment, while children who produced few novel actions in the first assessment had a higher chance. This decreased the chances of finding a significant relationship between the number of novel actions in both assessments.

The use of the same objects on both assessments was useful to assess the test-retest reliability of this specific measure. When divergent thinking in young children is assessed on only one occasion the Unusual Box test is a valid and reliable measure. However, for future studies that are specifically interested in the production of novel actions over several time points, it is advised that different objects and a box with different features are used.

When combining the results from both studies, age differences were found for both fluency and ratio originality scores, with older children performing on average more different and more original actions than younger children. This is in line with earlier findings that divergent thinking skills increase with age (a trend that continues until middle age: McCrae, Arenberg, & Costa, 1987). By inspecting the range of scores, it appears that while the lower end of the range stays stable across age, the upper end of the range increases with age. One possibility is that children of all ages perform basic actions, but with increasing age more sophisticated actions are added to their repertoire.

2.4 General Discussion

Our findings suggest that the Unusual Box test shows good psychometric properties. Examination of the test's concurrent validity indicates that fluency scores correlate well with other divergent thinking measures that are suitable for 3-year-olds – the TCAM (1981) and the Instances subtest of the Wallach-Kogan tests of creativity (1965). Furthermore, the Unusual Box test is characterized by high test-retest reliability over time in 2-year-olds both for fluency and ratio originality scores. The range in scores that we found on the Unusual Box test indicates that individual differences exist in children's divergent thinking. The brevity and simplicity of this measure contributes to the easy application of this test with children as young as 2 years of age.

As far as we know, the Unusual Box test is unique in that it uses novel objects to measure divergent thinking. In Study 2 we administered the Unusual Box test twice on the same children. The results showed that divergent thinking scores did not significantly change on the second assessment. Although children did perform actions on the second assessment which they performed on the first assessment as well, each child performed multiple novel actions that were not seen on their first assessment. This shows that although children have more experience with the novel objects, on multiple encounters they still produce novel actions. Therefore administering the Unusual Box test multiple times does not seem to have an effect on children's divergent thinking scores.

2.4.1 Individual Learning and Social Learning

Our results suggest that adopting a divergent thinking strategy could increase the impact of individual learning on cultural evolution. Children who explored more (fluency) also tended to find more different uses for an object, leading to higher originality scores. This finding highlights the important role that exploration plays in increasing variation in a culture, as emphasized by Mesoudi and Whiten (2004). The current study displayed individual differences in children's divergent thinking scores, indicating that some children are more likely to find novel uses for objects than others. In a 22-year longitudinal study, older children's divergent thinking scores on the Torrance Tests of Creative Thinking showed moderate to high correlations with their future creative achievements and careers (Plucker, 1999; Torrance, 1987). From a broader perspective, toddlers and preschoolers with high divergent thinking scores may in the future make a bigger contribution to cultural evolution than children with lower divergent thinking scores.

Further questions remain as to how individual learning and social learning interact. A study examining exploration by Bonawitz and colleagues (2011) suggests that in some situations social learning might actually have a limiting effect on divergent thinking. When an experimenter modelled an action on a novel object and gave pedagogical cues, toddlers copied the action more, and explored less, than when the experimenter did not model the action. This suggests social learning may limit divergent thinking. However Hoicka and Akhtar (2011) found that copying an experimenter's jokes allowed children to then create their own novel jokes. This suggests social learning may instead increase divergent thinking. Future studies should focus explicitly on the interaction between social and individual learning, to investigate how these types of learning complement or hinder one another.

The objects for the Unusual Box test are novel to the child and no modelling is provided by the experimenter. Therefore any actions performed by the child are self-initiated, making it possible to distinguish individual learning from imitation. This is an important advantage compared to the TCAM, which relies on examples and imitation in its explanation of the tasks. The Unusual Box test could thus complement on-going research on imitation and provide knowledge on how individual learning and social transmission interact to initiate cultural evolution, as there are no confounds with imitation in the Unusual Box test.

2.4.2 Age

Children's divergent thinking fluency and ratio originality scores increased with age. One possible explanation for this increase is that children's motor skills are not yet fully developed by the age of 2 years (Ireton & Vader, 2004). Therefore, an improvement in children's divergent thinking scores could be caused by an improvement in motor skills. In future studies, it would be beneficial to examine whether there is a relation between motor skills and divergent thinking through the Unusual Box test in younger toddlers.

However, previous research has shown that divergent thinking skills improve up until middle age (McCrae et al., 1987). Motor skills are unlikely to be the only factor behind an increase in divergent thinking scores up until middle age so other factors must influence divergent thinking as well. Kaufman and Kaufman (2004) proposed a 3-

stage framework of animal creativity, which we propose can be applied to young children as well. The first stage involves recognizing novelty, the second stage involves observational learning, and the third stage involves innovative behaviour. At a young age, children may derive more benefit from observational learning than from individual learning, because the amount of observed behaviour that is novel to the child is more abundant. When children then produce the observed behaviour themselves, we call it imitative rather than creative behaviour. However, for the child, performing this behaviour is novel and creative from their point of view, and may be just as valuable as individual learning. When a child gets older, a greater proportion of observed behaviour will be familiar and therefore individual learning might become more valuable to the child compared to observational learning, with children's divergent thinking skills improving as a consequence. Again, this reinforces the importance of examining the interaction between divergent thinking and social learning.

2.4.3 Intrinsic Motivation

The Unusual Box test is unique in comparison to other divergent thinking measures in that children are not prompted to think divergently. Therefore, divergent thinking scores obtained with the Unusual Box test reflect the child's own intrinsic motivation to think divergently and not necessarily the child's most creative output. However, the results show that the fluency scores of the Unusual Box test are positively correlated to the fluency scores of the Instances subtest and TCAM where children are prompted to give as many responses as possible. This suggests that whether or not children are prompted, they reveal similar individual differences in divergent thinking. One possibility is that children in general act on their highest level of divergent thinking, and prompting them to do so does not make them think more divergently. Runco, Illies, and Eisenman (2005) demonstrated that even slight changes in task instructions can influence participants' divergent thinking scores; however a control condition with no specific task instructions to be creative was omitted. Thus another possibility is that all children would get higher scores when prompted compared to when they are unprompted, but that children still display the same overall spread in divergent thinking scores. A final possibility is that prompting might influence some children but not others. Thus extrinsic motivation may act as a separate factor which could interact with children's intrinsic motivation to think divergently. Future research should investigate how prompting affects children's divergent thinking scores, and the extent to which children actually understand the task instructions.

2.4.4 Future Research

Future research should examine the intrinsic and extrinsic factors that might underlie individual differences in divergent thinking. These are likely to include novelty seeking (Kaufman & Kaufman, 2004), executive function (e.g., Carson, Peterson, & Higgins, 2003; De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012), and parenting styles (e.g., Bayard-de-Volo & Fiebert, 1977; Dreyer & Wells, 1966; Miller & Gerard, 1979). The Unusual Box test is also relevant for use in Artificial Intelligence and robotics in three ways. First, it can directly provide a tool to examine divergent thinking in robots, following recent embodied approaches to creativity in AI (e.g., Saunders, Gemeinboeck, Lombard Bourke, & Kocabali, 2010). Second, it highlights that divergent thinking can be for a large part intrinsically motivated, which converges with AI research which focusses on autonomy in creativity (e.g., al-Rifaie, Bishop, & Caines, 2012; Jordanous, 2012; Saunders, 2012). Third, by further examining physical, social, cognitive, emotional, and other factors that affect divergent thinking in early development, we can better understand how divergent thinking emerges, allowing for more sophisticated computational models of divergent thinking to be developed.

Finally, future research should investigate whether the Unusual Box test is suitable to use with children younger than 2 years of age. Children under 2 years have even less experience with objects. Thus research with younger toddlers might give us an even better insight into how children use individual learning to acquire knowledge about novel objects, with as little experience as possible from social learning. Furthermore, the non-verbal and non-imitative nature of the test makes it possible to use this test on special populations with communicative delays or disabilities such as deaf children of non-signing parents, or children with autism. Therefore this test might provide a more accurate index of divergent thinking in these populations, as communicative demands are more limited for the Unusual Box test than for the TCAM or Wallach and Kogan’s tests of creativity.

2.4.5 Conclusion

This paper demonstrates that the Unusual Box test is a valid measure of divergent thinking which can be reliably used with 2-year-olds. The test is recommended for young children over existing divergent thinking tests because of its non-verbal and non-imitative nature. This test allows us to gain insight into early emergence of divergent thinking, which is crucial for increasing our understanding of cultural evolution and innovation in society.

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Chapter 3

Preschoolers Generate their Own Communicative and Representational Iconic Gestures

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Abstract

In this paper we presented the first experimental study to investigate children's ability to generate their own iconic gestures (i.e., non-verbal gestures that symbolically represent a referent object) in order to communicate. Twenty 3.5- to 4-year-olds were presented with two objects, a target object which had a sticker attached to it and a distractor object. Children were asked to retrieve the object with the sticker. Crucially, the only way to retrieve the target object was through generating iconic gestures since it was impossible for children to communicate with the experimenter through other communicative means (i.e., talking or pointing). Children generated correct iconic gestures on 71% of the trials, and almost all iconic gestures produced represented the target object (97.3%). The results could not be explained through deferred imitation or automatic motor responses. These results corroborate previous literature which shows that children understand the communicative and representational nature of iconic gestures. Importantly, this research extends the previous literature by demonstrating that children can make use of their understanding of the communicative and representational nature of iconic gestures in the same way as adults do; namely to use them as a means to communicate with others.

Keywords: Iconic gestures, Communication, Representation, Preschoolers

3.1 Introduction

Gestures are an important part of communicative development (e.g., Acredolo & Goodwyn, 1988; Bernardis & Gentilucci, 2006; Goodwyn & Acredolo, 1993). Both language and gestures can symbolize objects and actions that are represented in the real world. The use of gestures is common in daily communication, and they are used in particular to clarify aspects that are harder to verbalize (Campana, Silverman, Tanenhaus, & Benetto, 2004). Gestures are said to aid speech, while speech inhibits the use of gestures (Bernardis & Gentilucci, 2006). This reinforces the idea that the communicative nature of gestures is different when used on their own compared to when used in combination with speech (Goldin-Meadow, 1999). This study focuses on children’s production of iconic gestures without speech. It investigates whether children are able to generate their own iconic gestures, and whether they understand the communicative and representational nature of their gestures.

Iconic gestures are non-verbal gestures that symbolically represent objects, events, desires and conditions (Acredolo & Goodwyn, 1988). They are often referred to as representational, referential, or symbolic gestures (e.g., Bates & Dick, 2002; Capirci, Contaldo, Caselli, & Volterra, 2005). Iconic gestures are different from deictic gestures (e.g., pointing) because an iconic gesture carries meaning as it symbolizes the referent, and the gesture is similar irrespective of context (Capone & McGregor, 2004).

Children produce iconic gestures from around 14 months (Acredolo & Goodwyn, 1988). At this age children's iconic gestures depict the function rather than the shape of objects, and tend to develop alongside word production (Acredolo & Goodwyn, 1988). Although children produce iconic gestures from this young age, they still do not seem to fully grasp the relation between an iconic gesture and its intended referent (Namy, 2001; Namy, Campbell, & Tomasello, 2004). This changes around 26 months, when children are more likely to associate iconic gestures with specific objects (Namy & Waxman, 1998; Namy et al., 2004) and also start using them more frequently (Özçalişkan & Goldin-Meadow, 2011).

Twenty-six-month-olds understand the communicative nature of iconic gestures. Namy (2008) taught children iconic gestures associated with familiar and novel objects. When the experimenter later asked for an object while performing the gesture, children were more likely to give the object associated with the iconic gesture than a distractor object. However, Namy et al. (2004) found that the gesture does not necessarily have to be iconic for children to understand the association between the gesture and object, as 14-month-olds and 4-year-olds responded similarly to arbitrary gestures and iconic gestures. This suggests that there is no advantage for iconic over arbitrary gestures early in development.

Children's understanding of the representational nature of iconic gestures develops from around 3 years. Twenty-six-month-olds show a preference for learning iconic over arbitrary gestures, suggesting that the representational aspect of a gesture aids children's understanding of that gesture (Namy et al., 2004). However, Tomasello, Striano, and Rochat (1999) found that 26-month-olds were only able to select the correct referent for iconic gestures when the gesture had been previously modelled in the context of using an object (e.g., hammering with a hammer on the floor during the model phase, and then hammering with a fist on the floor during the gesture phase). When the model action and iconic gesture were not identical (e.g., in the model phase rolling paper like a ball over the floor, and then in the gesture phase gesturing a throwing action) 26-month-olds had trouble selecting the correct referent. A possible explanation they give is that seeing the gesture in the context of the conventional use of the referent object activates the corresponding motor scheme that makes them retrieve the correct object. Only at 35 months did children recognize iconic gestures that were not modelled before. This may suggest that 26-month-olds rely on motor scheme activation, while 35-month-olds may understand the representational nature of iconic gestures.

Additionally, in an experiment by Tolar, Lederberg, Gokhale, and Tomasello (2008), children were shown an iconic gesture (in American Sign Language) and they had to choose which item out of four pictures was represented by the gesture. Two and a half-year-olds had trouble doing this, with only 2 out of 14 children performing above chance. From the age of 3 years children seemed to understand the iconicity of gestures. Children performed better with increasing age up until 4.5 years when all children performed above chance. Children found iconic gestures that represented the action of the referent (e.g., eating for spoon) easier to understand than iconic gestures that depict the static features of the referent (e.g., gesturing the contours of a house).

The literature to date focuses on whether children understand that other people's iconic gestures represent objects, and serve to communicate (e.g., Namy & Waxman, 1998, 2000; Namy et al., 2004; Namy, 2008; Tolar et al., 2008). However, little research focuses on children's generation of gestures. Some studies look at children's spontaneous production of gestures in a naturalistic setting (e.g., Acredolo & Goodwyn, 1988; Goodwyn & Acredolo, 1993; Özçalişkan & Goldin-Meadow, 2011), or they focus on children’s natural gesturing (not necessarily iconic gestures) in combination with speech (e.g., Goldin-Meadow, Wein & Chang, 1992; Morford & Goldin-Meadow, 1992). These studies give us great insight into the occurrence of gesture production from a young age. However, these studies do not shed light on the question as to whether children generate these gestures themselves (versus copying gestures), and whether they use them in the same way as adults do, namely to communicate to others.

Experimental research could help us determine whether children can themselves generate iconic gestures in order to communicate to others. Indeed, experimental studies show that children use deictic gestures (i.e., pointing) to communicate to others. Twelve-month-olds are shown to help others find objects by pointing at the correct location (Liszkowski, Carpenter, Striano, & Tomasello, 2006; Liszkowski, Carpenter, & Tomasello, 2008). Furthermore, Knudsen and Liszkowski (2012a) found that 18-month-old children inform an ignorant experimenter when the location of a target object was changed by pointing to the new location. Also, when a desirable toy was replaced by an aversive object, children pointed to the location where the desirable toy was before, supposedly to warn the experimenter that they would grab the aversive object instead (Knudsen & Liszkowski, 2012b).

Furthermore, experimental research could help us determine whether children understand the representational nature behind the iconic gestures they themselves have generated. Experimental studies on pretending show that 3.5-year-olds use gesture-like actions when the objects they want to pretend with are absent (e.g., pretending to drink without a cup being present; Elder & Pederson, 1978; Boyatzis & Watson, 1993). This suggests that from 3.5 years children have some understanding of the representational nature of iconic gestures. However it is not clear from this study whether children use such gestures in a communicative capacity. Experimental research on children’s production of iconic gestures could give insight into whether children are capable of generating iconic gestures on their own, and whether they understand both the communicative and representational nature of iconic gestures.

This study investigated whether children can generate their own iconic gestures, without watching someone make the gesture beforehand, to request an object with a sticker. The idea to request stickers as a goal was derived from a study by Matthews, Lieven, and Tomasello (2007). Our first major goal was to determine whether children could generate gestures in order to communicate. To make the use of iconic gestures as natural for children as possible, and inhibit the use of more common ways to communicate (i.e., talking or pointing), the study was set up to make it impossible for children to retrieve the sticker through these other means. There were two objects on the table of which only one had a sticker attached. The two objects were placed close together so that when a child pointed to the desired object it was not clear which of the two s/he wanted. Furthermore, the experimenter who was giving the objects was wearing headphones and the child was told she was listening to music so she could not hear what the child was saying. Therefore gesturing was the only option for children to get their message across. If children would generate their own iconic gestures, this would indicate that children do indeed understand the communicative nature of iconic gestures.

Another major goal was to determine whether children understand the representational nature of their iconic gestures. Children had to generate the correct iconic gesture that represented the target object in order to get the sticker. Other iconic gestures (e.g., gesturing the other object on the table, or making an arbitrary gesture) would not allow them to retrieve the sticker. Therefore a correct iconic gesture would display children’s understanding of the representational link between the iconic gesture and the object.

A secondary aim of the study was to examine whether the types of actions generated by children were the result of an automatic motor response. One could argue that, upon seeing an object, children have an automatic motor response to perform the action in accordance with it, and that when there is no option to perform the action with the object itself, it would resemble an iconic gesture (e.g., Tomasello et al., 1999). If it were automatic motor activity driving the generation of iconic gestures, one would expect to see only representation gestures, in which the gesture type resembles the position and action of the hand when using the object. Research by Boyatzis and Watson (1993) argues against this possibility. They asked 3- to 5-year-olds to pretend to use common objects that were not in the room (e.g., toothbrush). Three- and 4-year-olds mostly produced body part gestures, in which they used part of their body to substitute the object being represented. This supports the idea that the generation of iconic gestures by 3-year-olds is not driven by automatic motor responses, and we expect similar results for our study.

Another secondary aim was to determine whether children’s production of gestures might be caused by deferred imitation. Özçalişkan and Goldin-Meadow (2011) found that children’s production of gestures was associated with the number of gestures produced by parents. Although they did not specify whether the children produced the exact same gestures, one could argue that having seen iconic gestures being produced by parents increased the chance that children would produce similar gestures. In order to find out whether children have a tendency to copy gestures from others, we included a model phase in our study. If children do prefer to copy gestures they have seen before, we would expect them to imitate the modelled gestures. If they do not imitate the type of modelled gestures (i.e., representation gestures), but instead produce other types of gestures (e.g., body part gestures) it would argue against deferred imitation. Furthermore, direct imitation of the experimenter's iconic gesture would show that children can imitate the production of an iconic gesture but it could not shed light on whether children understand the communicative value of the gesture. However if children produce a correct gesture using one of the other gesture types, it would indicate that children copied the goal to produce an appropriate gesture.

A final secondary aim was to determine whether children would use more sophisticated gestures when the communicative context was more ambiguous, i.e., when the target and distractor objects had similar gesture locations (e.g., toothbrush and lipstick) or the iconic gestures of the target and distractor objects looked alike (e.g., hammer and shaker). For example, when a cup and a ball are presented together, simply pointing to the mouth would be enough to understand which of the two objects the child is requesting. However, when a cup and a spoon are presented together, pointing to the mouth would not be enough to distinguish between the target and distractor object, and the child would have to make a more sophisticated iconic gesture to make clear which of the two s/he wanted. Therefore when easy, unambiguous, pairs of objects were presented we expected that children would be more likely to use a simple iconic gesture (e.g., pointing at correct location), while when difficult, ambiguous pairs of objects were presented they would use more sophisticated gestures (e.g., representation).

3.2 Method

3.2.1 Participants

Twenty children participated (13 males, *mean age* = 42.5 months; *range* = 40 – 48 months; *SD* = 3.3 months). An additional eight children were excluded due to a lack of response during the model phase (5), or experimental error (3). Children were recruited from a database of parents that had responded positively to a letter asking their child to participate in studies on child development. All children were Dutch.

3.2.2 Materials

The apparatus consisted of 22 objects that were familiar to 3-year-olds. They were either daily used household objects (e.g., toothbrush, tissue) or objects that were frequently used in children's play (e.g., drum, microphone; see Appendix C, p. 170 for a full list of objects). The experimenter who sat next to the child (E1) had two sticker trees. These were sheets of paper each showing a picture of a tree which contained white circles on which round stickers could be placed. The sticker tree with 3 circles was for the experimenter, and the sticker tree with 9 circles was for the child. The second experimenter who sat opposite the child (E2) had 12 stickers to give to the child and E1. She was wearing large headphones that were covering her ears completely, to indicate she could not hear anything that was being said. Next to her was a small table containing 18 out of a possible 22 objects. The objects were hidden from the view of the child with a cardboard screen that was standing on the same table.

Two video cameras (brand?) were used to record the child's and experimenters' behaviour. One camera was directed towards the child and E1. The other camera was directed towards E2. See Figure 1 for an overview of the setup.

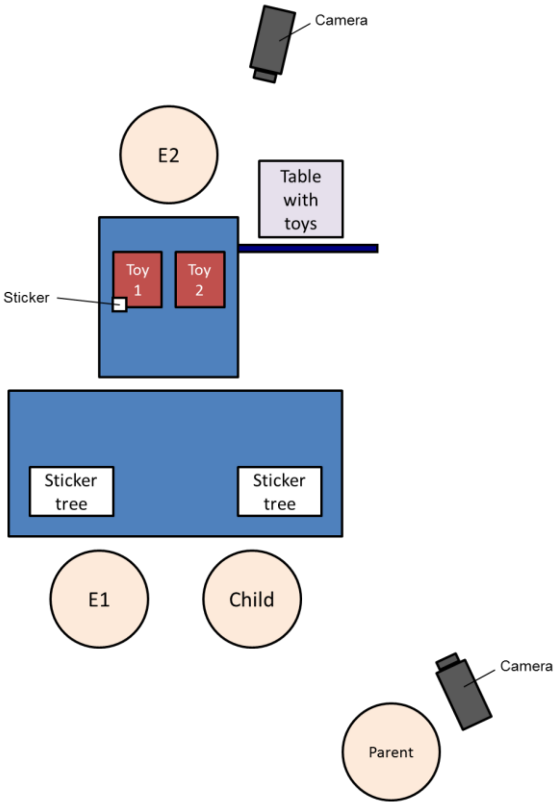

Figure 1: Overview of the setup of the study.

3.2.3 Design

A between-subjects design was used. Each trial consisted of two objects being presented to the child. In order to find out whether children would use more sophisticated gestures when the communicative context was more ambiguous, we included easy and difficult object pairs. The object pair was considered easy when the iconic gestures representing the objects were very different from each other (e.g., glasses and microphone); or difficult, when the iconic gestures looked alike (e.g., hammer and shaker), or when the objects were used on a similar part of the body (e.g., toothbrush and lipstick). One of the objects had a sticker attached to it using blue tack. The object on which the sticker was placed was counterbalanced.

The study consisted of two phases: a model phase (3 trials) and an extension phase (6 trials). The design of a model and extension phase was developed by Hoicka and Akhtar (2011). The model phase allows children to learn the rules of the game and it gives the opportunity to investigate children's ability to produce iconic gestures without the necessity to understand the communicative and representational nature of the iconic gestures. The extension phase shows us whether children can generate iconic gestures without a model and whether they understand the communicative and representational nature of iconic gestures. For the model phase, 3 pairs of objects were used (see Appendix C, p. 162). wo of the pairs were considered easy, and the third pair was considered difficult. The order of objects given to children was counterbalanced, although the first trial was always an easy pair. For the extension trials 16 objects were used. Each object was paired with an object in an easy and difficult pair (see Appendix C, p.162). For example, the hat was paired with a paintbrush in an easy trial, and with a hairbrush in a difficult trial. To make sure that no object was presented twice in consecutive trials, 16 object pairs were required (8 easy, 8 difficult). Six pairs of objects were used for each participant. Difficult and easy pairs were always alternated. The order of the objects, the object on which the sticker was placed, and whether the extension trials started with an easy or difficult pair were counterbalanced.

3.2.4 Procedure

Children came into the lab with one of their parents. The study started with a short warm-up in which the child completed a puzzle with E1 who was sitting next to the child, while E2 sat on a chair at the side and interacted minimally. Children were allowed to sit on their parent's lap during the warm-up. After the warm up, the parent sat approximately 1 meter behind the child (see Figure 1). E1 told the child that they would play a fun game in which they could win lots of stickers. She showed the child both sticker trees, gave the bigger tree (with 9 circles) to the child and kept the smaller one (with 3 circles). E2 then placed two objects close together on the table, out of reach of the child, and performed the actions associated with both objects (e.g., putting the glasses on and singing into the microphone) to make sure that the child knew what action was associated with the object. E2 made sure that the child was watching while she performed the actions. E1 also drew attention to the toys by saying their names and pointing in the direction of the toys. Next, E2 placed a sticker on one of the objects. E1 responded enthusiastically, saying, "Ah, a sticker. I want to have it. I am going to ask for the sticker". She would then ask E2 verbally for the object with the sticker. However, because E2 was wearing headphones she could not hear what was being said and responded by shrugging her shoulders and looking confused. E1 explained to the child, "Oh no, she cannot hear us. We have to ask for the sticker in another way. Why don't we try pointing at the one we want?" She then pointed at the object that had the sticker attached to it. E2 would again respond by shrugging her shoulders and looking confused. E1 explained, "Oh no, the objects are too close together, so she does not understand which one we want. Why don't we gesture the action of the object and see if she understands that." E1 would then make the iconic gesture that represented the object with the sticker. In response E2 smiled and handed the object with the sticker to E1. E1 took the sticker from the object, placed it on her sticker tree, and gave the object back to E2. E2 placed a new sticker on the same object and E1 said enthusiastically to the child, "Now you try!" The child was then allowed to respond. Table 1 displays the possible actions performed by the child and the respective responses by E2. E1 responded to an incorrect response with, "She does not understand. Can you try a different way?" If the child did not respond after approximately 15 seconds, E1 would prompt the child saying, "How could you show [E2] which object you want?" If the child still did not respond after approximately 15 seconds, E1 would say to the child, "Do you remember what I did? I was making this gesture, right?" while showing the gesture to the child. When E1 showed the gesture to the child E2 looked away so that she would not respond to the gesture performed by E1. If the child remained non-responsive after approximately 15 seconds, E2 would take the objects away and replace them by two new objects. The next two model trials were similar to the first trial, with the exception that E1 immediately performed the correct iconic gesture (omitting the talking and pointing).

After the model phase, E1 showed her sticker tree to the child saying, "Now my sticker tree is full, but you still have room for more stickers. Now it's your turn!" For the extension phase (6 trials) the child had to request the object with the sticker without any help from E1, that is, E1 never modelled any more gestures. The actions and responses by E2 were similar to the model trials.

Table 1: Possible actions by child and E2's responses to those actions

Child's action	**E2's response**
Speaking	Shrugged shoulders and looked confused
Pointing at object	Shrugged shoulders and looked confused
Irrelevant / unclear gesture	Shrugged shoulders and looked confused
Speaking + Pointing at object	Shrugged shoulders and looked confused
Gesture other object on table	Gave the other object to the child (taking it back if child did not take the toy).
Correct Gesture - Pointing at correct location - Action movement - Body part gesture - Representation	Smiled and gave the object with the sticker to child
Speaking + Correct gesture	Smiled and gave the object with the sticker to child
No Response	After 30 seconds of not responding she took toys away and started a new trial.

3.2.5 Coding

Children who responded on at least one model trial were included in the final analyses. For each trial, the types of actions the child produced were coded (see Table 1 for an overview of possible actions). Only the last action performed was used for analyses, or when E2 had missed a correct gesture (2 trials), the last correct gesture was used. Furthermore, it was coded whether the child had performed a correct gesture at some point during the trial or not (binomial coding). There were four gesture types that counted as a correct gesture: 1) Pointing at correct location; when a child pointed at the location in which the object would be used (e.g., teeth for toothbrush, head for hat). However, this gesture type only counted as a correct gesture for easy object pairs, when pointing at the location was sufficient enough to distinguish between the objects on the table. 2) Action movement; when a child performed the movement that one would make with the object but nothing else resembled a representation of using the object (e.g., hitting the table for drum, moving arm over table for paintbrush). 3) Body part gesture; when a child used his/her body as part of the object being gestured (e.g., using hand as a shovel, moving the back of the hand over the table and turning hand around as if dropping something off the shovel). 4) Representation; when a child performed the action the way s/he would do if s/he had the object in hand (e.g., for toothbrush holding hand as if holding the toothbrush and moving it in front of mouth).

3.3 Results

3.3.1 Model trials

The results showed that children produced a correct gesture on 44 out of 60 trials (73%). We modelled the likelihood of getting a correct response during a trial using logit mixed effect models with the LME4 package (Bates, Maechler, & Dai,

2008) in R (R Development Core Team, 2008). According to Jaeger (2008) it is more appropriate to analyse repeated-measures categorical data with logit mixed effect models, compared to ANOVAs. We first built a base model, which included an intercept and Participant and Object as random variables. For all mixed logit models, we compared the base model to models including Difficulty (Easy, Difficult), Gender (Male, Female), Age Group (Older, Younger), and the interaction between Difficulty and Age Group. None of these factors improved the base model for the Model trials. The resulting model (*log-likelihood* = -27.97, *N* = 60) found children were significantly more likely to produce a correct response (correct gesture) during a trial than to give an incorrect response (*OR* = 115.7, *p* = .005).

In the model phase, children were able to imitate a modelled iconic gesture performed by E1. This gesture was always a representation gesture type, in which E1 used her body the way she would when she would actually perform the action with the target object. Out of the 44 correct gesture responses, children imitated the representation gesture type on 6 trials (14%), and used another gesture type (either pointing at correct location, action movement, or body part gesture) on 38 trials (86%). Logit mixed effect models were run on the correct gestures only. We compared the base model to the previous independent variables, as well as (crucially) gesture type (Representation, Other). Children were significantly more likely to produce one of the other gesture types than to copy the representation gesture type (*log-likelihood* = -17.15, *N* = 44; *OR* = 8.65, *p* < .001). This indicates that children copied the goal to perform an iconic gesture, rather than blindly mimicking the modelled gesture.

Table 2: number of trials in which children responded, separately for each behavioural response, and percentage of the total number of trials (N = 105) in which a certain response was given. Only the last response of the child of each trial was taken into account.

Behavioural response	**Number of trials**	**% of total number of trials**
Speaking	**15**	**14.3**
Pointing at object	**2**	**1.9**
Speaking + Pointing at object	**0**	**0.0**
Showing	**1**	**1.0**
Irrelevant / unclear gesture	**3**	**2.9**
Gesture other object on table	**0**	**0.0**
Correct Gesture	**74**	**70.5**
- Pointing at correct location	0	0.0
- Action movement	26	24.8
- Body part gesture	28	26.7
- Representation	20	19.0
Speaking + Correct gesture	**0**	**0.0**
No Response	**10**	**9.5**

3.3.2 Extension trials

Children performed 105 extension trials in total. Table 2 shows the number of times each behaviour was performed over all 105 trials. Children performed a correct gesture on 74 trials (71%). We modelled the likelihood of giving a correct response during a trial using logit mixed effect models. We first built a base model, which included an intercept and Participant and Object as random variables. We built our model as in the Model trials. None of the factors improved the base model. The resulting model (*log-likelihood* = -36.38, *N* = 105) found children were significantly more likely to give a correct response (correct gesture) during a trial than to give an incorrect response (*OR* = 37.08, *p* = .0335).

Fourteen out of 20 children performed a correct gesture on at least one of the trials, χ^2 (1) = 3.20, $p = 0.074$. Out of the 6 children who did not perform a correct gesture, 4 of them did not complete all extension trials (3 children completed 2 trials, 1 child completed 3 trials).

3.3.2 Correct Gesture Types

We investigated whether children tended to use one gesture type more often than other types. Only the 14 children who actually performed correct gestures were analysed (10 males, *mean age* = 42.9 months; *range* = 40 – 48 months; *SD* = 3.5 months). A one-way repeated measures ANOVA was used with Gesture Type as the within-subject variable and 3 levels (action movement, body part gesture, and representation). The gesture type ‘Pointing at correct location’ was not included in the analysis because children never used this gesture type in the extension phase. No differences of Gesture Type were found, F (2,26) = 0.641, $p = 0.535$, indicating that there was no preference for the use of a specific gesture type. Age Group and Gender did not affect this result.

Only one child performed one gesture type for all trials, while 5 children performed two gesture types, and 8 children performed all three gesture types. Children were more likely to use two or more different gesture types, χ^2 (1) = 10.286, $p = 0.001$.

To find out whether children would use a specific type of gesture to communicate about certain objects, we investigated how many gesture types were performed for each object. Three objects (Drum, Pen, and Soap) elicited only one type of gesture, while 9 objects elicited two types of gestures, and 4 objects elicited all three types of gestures. These results suggest that children were more likely to use two or more different gesture types rather than using a specific gesture type to communicate about an object, χ^2 (1) = 6.250, $p = 0.012$.

It is possible that children attuned the gesture type they produced dependent on how similar the iconic gestures of the object pairs were (Difficulty). In that case we would expect children to perform more sophisticated gesture types (i.e., body part gesture, representation) and less easy gesture types (i.e., location indication, action movement) on the difficult object pair trials, compared to the easy object pair trials. We modelled the likelihood of performing a sophisticated gesture type during a trial using logit mixed effect models. We first built a base model, which included an intercept and Participant and Object as random variables. We compared the base model to models including Difficulty (Easy, Difficult), and the interaction between Difficulty and Age Group (Young, Old). None of these factors improved the base model. The resulting model (*log-likelihood* = -44.97, *N* = 105) found children were significantly more likely to perform a sophisticated gesture type than to perform an easy gesture type (*OR* = 2.46, *p* = .0244). This indicates that children did not attune their gestures specifically to how similar the iconic gestures of the object pairs were, but were overall using more sophisticated iconic gestures to communicate.

3.4 General Discussion

The results show that children generated iconic gestures on most extension trials to communicate with the experimenter. The majority of the iconic gestures generated (97.3%) represented the target object, confirming our predictions that children understand the communicative and representational nature of iconic gestures. Previous literature showed that children from around 26 months old understand that other people use iconic gestures in a communicative way (Namy, 2008; Namy & Waxman, 1998; Namy et al., 2004; Tomasello et al., 1999). Our results extend this literature as the children in our study generated iconic gestures themselves in order to communicate.

Therefore children not only understand that others can use gestures to communicate, but are able to take advantage of this communication form themselves.

Children’s understanding of the representational nature of iconic gestures develops around 26 months when they are more likely to associate iconic gestures with specific objects (Namy & Waxman, 1998; Namy et al., 2004), but it is not until 3 years of age that they really seem to understand the iconicity of gestures (Tolar et al., 2008). Our results showed that children generated iconic gestures to refer to a specific target object, rather than generating arbitrary gestures, a gesture for the wrong object, or no gestures at all. This suggests that from 3.5 years, children not only understand the representational nature of gestures, but can use this representational understanding to create their own appropriate gestures.

Furthermore, previous work has shown that children generate iconic gestures in a natural setting (e.g., Acredolo & Goodwyn, 1988; Özçalişkan & Goldin-Meadow, 2011), which implies that children understand the association between iconic gestures and their referents. The results of our study extend this literature by demonstrating children’s cognitive understanding of the communicative and representational nature of iconic gestures. It gives support for the idea that children in the naturalistic settings may understand the communicative and representational nature of iconic gestures as well, although one must take into account that most naturalistic studies involve younger children, therefore their cognitive abilities might still be limited.

3.4.1 Imitation

It is possible that children did not generate their own iconic gestures, but instead imitated previously seen gestures (i.e., deferred imitation). Although this possibility cannot be ruled out, it seems highly unlikely that all iconic gestures generated by the children relied on this method. First of all, the results showed that in the model trials, when they had the option to imitate an experimenter who modelled an iconic gesture, children did not use direct imitation. Instead of producing the identical gesture (representational gesture), they generated a different gesture type 86% of the time (a combination of action movement and body part gestures). If children are not likely to imitate gestures that were presented to them a few moments beforehand, it seems unlikely that they would use deferred imitation to guide their iconic gesture production in the extension trials.

Second, not all objects presented are well known for being common gestures (e.g., watering can, harmonica). This makes it highly unlikely that children will have seen all iconic gestures for the objects in the extension trials, such that they would produce all gestures using deferred imitation.

Future research could use novel objects to rule out the possibility of deferred imitation. However we chose to use familiar objects because children’s ability to generate iconic gestures for well-known objects may be influenced by their previous knowledge about the objects. Poggi (2008) argues that in order to generate iconic gestures we select the features to imitate based on their distinctiveness and their ease to be represented by hands. One could therefore argue that children would be better at generating iconic gestures for familiar objects because they are familiar with the actions performed with the objects and therefore are better able to decide what the distinctive feature of the object is to include in their iconic gesture.

3.4.2 Automatic Motor Responses

It may also be argued that children did not generate their own iconic gestures, but instead demonstrated automatic motor responses. However if it were the case that children produced gestures based on the motor memory of what to do with that object, one would expect children to only produce representation gestures. However during the model trials, children mostly produced gestures that were not representation gestures; instead they mostly used action movement and body part gestures. Additionally, during the extension trials children generated representation gestures only a third of the time – in equal proportion to their generation of action movement and body part gesture types. For the action movement and body part gesture types, children position their hand differently than what they would do when using the object. This indicates that children do not rely on automatic motor activation to generate iconic gestures. This is confirmed by previous studies which show that children use different gestures types when producing iconic gestures (e.g., Acredolo & Goodwyn, 1988; Boyatzis & Watson, 1993).

3.4.3 Different Types of Iconic Gestures

When looking at the correct gestures children performed, children did not show a preference for a certain gesture type. Although pointing at the correct location was never performed in the extension trials, the other three gesture types (action movement, body part gesture, and representation) were generated equally. This is contradictory to findings by Boyatzis and Watson (1993) who found that 3- and 4-year-olds mainly produced body part gestures. Our findings suggest that children have more plasticity in the use of iconic gestures, such that children decide per trial which gesture type is best to use.

However, children did not adjust their iconic gestures based on how much the objects on the table necessitated similar or different gestures. Children used more sophisticated gestures (body part gesture, representation) than easy gestures (location indication, action movement), irrespective of whether the object pair was easy of difficult. This indicates that 3-year-olds have the capacity to make sophisticated gestures and suggests that they prefer these over easy gestures. One possible explanation for this could be that 3-year-olds understand that the sophisticated gestures are more iconic and therefore less likely to be confused for another gesture, and that it will be more likely for the receiver to understand the message correctly if they make a more sophisticated gesture.

Finally, the objects themselves did not dictate the types of gestures that children generated. Objects have certain physical affordances that young children can detect (Bourgeois, Khawar, Neal, & Lockman, 2005), lending themselves to specific actions. However it does not appear to be the case that objects have any type of “gesture affordances” which bias children to use one gesture type over another.

3.4.4 Conclusion

In this paper we presented the first experimental study to investigate children’s ability to generate their own iconic gestures in order to communicate to others. The results showed that 3.5- to 4-year-olds are indeed able to generate their own iconic gestures to represent a target object in order to retrieve a sticker. These results corroborate previous literature which shows that children understand the communicative and representational nature of iconic gestures. Importantly, this research also extends the previous literature by demonstrating that children can make use of their understanding of the communicative and representational nature of iconic gestures in the same way as adults do; namely to use them as a means to communicate with others.

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Chapter 4

Preschoolers understand and generate their own pretend actions using object substitution

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Abstract

Previous studies on children's ability to generate object substitution actions are limited in that they cannot confirm whether children understand the representational nature of object substitution (i.e., using an object 'as if' it is something else). Alternative explanations to children's ability to generate pretend actions in these studies are that they use imitation or specific prompts from the experimenter to guide their actions. The key aim of this paper was to investigate children's ability to generate object substitution actions without help from others. Second, their ability to differentiate an experimenter's intentions to pretend or to try and perform a genuine action was investigated. In Study 1, 45 3- and 4-year-olds were either presented with pretend actions, accompanied by cues to state the intention to pretend, or trying actions, accompanied by cues to state the intention to perform a genuine action. Children successfully differentiated between the experimenter's intentions, and generated more object substitution after pretend actions had been modelled in previous trials. The results extend previous research by confirming children's understanding of the representational nature of object substitution and their ability to generate object substitution actions. Study 2 replicated these findings with 34 3-year-olds, but in addition found no relationship between children ability to generate object substitution actions and divergent thinking, inhibitory control, or the use of object substitution during free play. This contradicts previous literature, for which possible explanations are discussed.

Keywords: Pretend Play; Object Substitution; Divergent Thinking; Inhibitory Control; Naturalistic; Observational

4.1 Introduction

Pretend play differs from other types of play in the sense that the actions performed during pretend play are technically ‘wrong’. For example, drinking from a cup that is empty, walking around with a stuffed toy dog that is not really alive, or soothing a baby doll that is not really crying. Sometimes children also substitute one object for another (e.g., pretending that a banana is a phone). Object substitution requires the ability to temporarily suppress the original action that fits the object while performing the action of the object you are substituting it for. Children as young as 2 years are shown to use object substitution during pretend play (Fein, 1981; McCune-Nicolich, 1981; Vig, 2007). However, it is not clear from these studies whether these children really understand the representational aspects of their own use of object substitution; that is whether they really use the object ‘as if’ it is the other object. Also, it is not clear whether, when another person performs an object substitution action, children really understand that this person does the ‘wrong’ action intentionally. This study sought to investigate both questions by investigating children’s ability to generate pretend actions, and their ability to interpret an experimenter’s intentions to pretend using object substitution.

Children's pretend play develops during the first years of life. Before their first birthday children mainly physically manipulate objects, while they learn how to use the objects properly (McCune-Nicolich, 1981). Around 12 months, children start using normal actions in a playful way, for example drinking from a cup that is empty. This is called auto symbolic play (McCune-Nicolich, 1981; Vig, 2007). Auto symbolic play further develops by using others (e.g., dolls) to do similar play actions (around 18 months; McCune-Nicolich, 1981; Vig, 2007), followed by making sequences of play actions (during the second year; McCune-Nicolich, 1981; Vig, 2007). The final stage develops towards the end of the second year and into the third year. During this stage children are less object driven, and internally direct what to play. For example, children decide beforehand what they want to play and then search for the objects that go with that play scenario. During this stage they are also starting to show the ability to substitute objects for others (Fein, 1981; McCune-Nicolich, 1981; Vig, 2007).

4.1.1 Generation of object substitution actions

Naturalistic research suggests that children perform object substitution actions in a free play setting from the age of two (e.g., Belsky & Most, 1981; McCune-Nicolich, 1981; McCune, 1995). However these studies only mention the incidences of object substitution and do not provide any information on the content of their play. Therefore, it is hard to tell whether children's object substitution actions are generated by themselves or whether they are copied from others (immediately after observation or using deferred imitation). If the latter were the case one cannot know for sure whether children were really representing the substituted object, which is argued to be the case (Vig, 2008). Experimental studies suggest that children under 3 years still rely on the substituted object being similar to the pretend object (Elder & Pederson, 1978). For example, they use a straw to represent a spoon, or a tissue to represent a blanket. This suggests that children still rely on physical similarities between the object present and the pretend object, and therefore might not fully display representational abilities.

Experimental research suggests that children understand and produce object substitution actions from around 3 years (e.g., Harris & Kavanaugh, 1993; Wyman, Rakoczy, & Tomasello, 2009). Harris and Kavanaugh (1993, experiment 2) presented children with pretend play scenarios in which they substituted blocks for other objects. First the experimenter performed a pretend action (e.g., feeding a toy monkey a banana, in which the banana was a yellow block), after which the child was asked to perform the same action ("You give the monkey some banana"). Most children successfully produced an object substitution action (they brought the yellow block to the monkey's mouth). However, similar to the naturalistic research, we cannot rule out that children simply imitated the experimenter's actions without really understanding the representational aspect of object substitution.

In a follow-up study, children were introduced to a pretend play scenario, but the exact action which the child had to perform was not modelled (Harris & Kavanaugh, 1993, experiments 3 and 4). For example, the experimenter pretended to pour tea into an empty cup containing a popsicle stick. He then handed the cup to the child and said, "Show me how you stir Teddy's tea with the spoon". Most children successfully performed this action, thereby showing that children did not require a model to perform object substitution.

The downside of this study and similar studies that investigate children's ability to generate pretend actions (e.g., Rakoczy, Tomasello, & Striano, 2004; Rakoczy & Tomasello, 2006) is that experimenters gave prompts to children to generate specific pretend actions. For example, Harris & Kavanaugh (1993) asked specifically to show how to stir, or, in an attempt to decrease the amount of lexical information given, they asked to “show what Teddy does with a spoon”. These cues might have prompted a child to perform a stirring action (because that is what one does with a spoon) without necessarily representing the popsicle stick as a spoon.

In addition, the pretend scenario itself might have prompted children to give a specific response without really understanding the representational aspects of the pretend actions. For example, the fact that the popsicle stick was already in the cup when being handed to the child might have prompted an automatic motor response from the child to stir the stick in the cup. Also, the objects used for object substitution were chosen for their resemblance in shape to the substituted object (e.g., a popsicle stick as a spoon, or a piece of paper as a towel) which limits the necessity to use representative abilities.

In summary, although naturalistic and experimental research suggests that children around 3 years understand and generate object substitution actions, they cannot rule out children’s reliance on imitation or on verbal and behavioural prompts to generate these actions. Therefore, this study sought to investigate whether children can generate object substitution actions without providing a model or giving specific verbal and behavioural prompts.

4.1.2 Understanding intentions behind object substitution

An essential skill behind understanding pretence is to understand that the person who is pretending is intentionally doing something ‘wrong’. Rakoczy, Tomasello, and Striano (2004) showed that 3-year-olds understood the intentionality behind pretending when using auto symbolic pretend play (i.e., using the original object to pretend with). They showed children either a person pretending to do an action or trying to do an action correctly but failing to do so (e.g., writing with a pen that still had the cap on). The difference between the two groups was that in the pretend group the experimenter showed verbal and non-verbal cues to indicate it was his intention to pretend (e.g., playful expression, making sound effects). These verbal and non-verbal cues were similar to the cues mothers gave to their children when pretending to eat a snack in a more naturalistic setting (Lillard, 2006). On the other hand, in the trying group he showed verbal and non-verbal cues to indicate it was his intention to perform the genuine action (e.g., frustrated expression, stating surprise by saying, “Hmmm?”). They found that 3-year-olds imitated the pretend actions while correcting or trying to correct the trying action (e.g., taking the cap off the pen before colouring).

Explicit verbal instructions can aid children’s understanding of pretending. During a training phase, Rakoczy, Tomasello, and Striano (2006) told one group of children explicitly that a person was ‘pretending to’ or ‘trying to’ do a certain action before doing the pretend or trying actions. Another group of children only received implicit cues that the person was pretending or trying (e.g., pretending a shoe was a cup, while saying, “this is her cup and she is drinking”), and a third group received no specific pretend training. When 3-year-olds were asked whether an action performed was pretending or trying during test trials, they were more likely to give a correct response when they received the explicit training than when they received the implicit training or no training. This suggests that providing children with the direct association between the pretend action and the word ‘pretending’ aids children in their understanding of the intentionality of these actions.

We were interested to see whether, and if so how, children understood the intentions behind pretending when using object substitution. In Study 1 we investigated whether children could distinguish between an experimenter’s pretend and trying actions. We used similar verbal and non-verbal cues to distinguish between the pretend and trying actions as in Rakoczy *et al.* (2004). Furthermore, we compared children in an explicit and implicit group to further investigate the effect of explicit instructions on children's ability to use object substitution. In congruence with Rakoczy *et al.* (2004), we expected that children would pretend after the experimenter performed a pretend action, and would perform a correct action with the object after the experimenter performed a trying action.

4.1.3 The influence of Divergent Thinking and Inhibitory Control on children's ability to generate object substitution actions

The ability to generate novel pretend actions without a model is thought to require additional skills to what a child would require to understand others' pretend actions. One skill that might be important in the generation of novel pretend actions is divergent thinking, i.e. the ability to think of multiple uses for an object. Through exploration, some children are able to think of many uses for an object while others only perform a few actions (Bijvoet-van den Berg & Hoicka, Chapter 2). Children's divergent thinking skills have been linked to children's imagination abilities during pretend play. Russ, Robins, and Christiano (1999) found that fantasy and imagination in pretend play predicted divergent thinking. Wyver and Spence (1999) initially found no correlation between children's divergent thinking scores and how much they pretended with objects. However, they did find that when children received training in thematic play, in which children use activities and themes in their pretend play that are remote from those encountered by the child in their everyday live, children's divergent thinking scores increased. Also, when children received training in divergent thinking their frequency of thematic play behaviour increased. This suggests that children's divergent thinking skills are related to children's ability to think beyond what is normal to their everyday life. This ability to think beyond what is normal might help children during the generation of object substitution actions as well. During object substitution, one has to think beyond the normal use of the object and instead project the use of a different object onto it. Therefore, divergent thinking might be related to children’s ability to generate object substitution actions.

Another skill that might be important in the generation of novel pretend actions is inhibitory control. Inhibitory control is the ability to suppress or delay an impulsive response when a task calls for it (Carlson & Moses, 2001). This skill seems important when using object substitution, where you need to inhibit the original action performed with an object and perform the pretend action instead. In the past, children’s lack of pretence in autism has been explained by a difficulty to inhibit initial responses (Harris, 1993). This means that when children were for example presented with a hammer and asked to pretend it was something else, they found it difficult to inhibit the initial response to use the hammer in the original way and therefore failed to perform the pretend action. In normally developing children, inhibitory control has also been linked to children’s symbolic play skills (Kelly, Dissanayake, Hammond, & Ihsen, 2011). Study 2 sought to further investigate the relationship between divergent thinking, inhibitory control and the ability to generate object substitution actions.

4.1.4 Comparing experimental and naturalistic research

A final aim of this paper was to investigate whether the results from our pretend experiment were comparable to children’s pretend play behaviour in a naturalistic play setting. Most studies on pretend play focus either on investigating specific abilities using experimental designs (e.g., Onishi, Baillargeon, & Leslie, 2007; Rakoczy et al., 2004, 2006; Wyman, Rakoczy, & Tomasello, 2009) or detecting more overall developmental patterns of pretend play using naturalistic settings (e.g., Belsky and Most, 1981; Howes & Matheson, 1992; Lillard & Witherington, 2004; Wyver & Spence, 1999), but rarely have these two designs been assessed together. It is important to study these two designs together to get a better picture of how individual differences in specific abilities relate to differences in naturalistic play behaviour.

An exception is the study by Kelly *et al*. (2011). In this study, spontaneous pretend play of children aged between 4 and 7 years old was assessed in a 20-minute unstructured free play with 15 functionally specific toys (e.g., toy truck) and junk items (e.g., cardboard box). Symbolic play acts constituted both auto symbolic and object substitution acts. Children's ability to engage in three different types of pretend play (one of which was object substitution) was assessed using the Test of Pretend Play (ToPP; Lewis & Boucher, 1997). In this test pretend play was modelled for the child to copy. Furthermore, children were verbally instructed to carry out specific play actions or perform novel pretend play. They found that children's ability to imitate pretend actions was correlated to the percentage of time they spent pretending during free play. In Study 2, we investigated whether the amount of time 3-year-olds spent pretending, and specifically performing object substitution actions during free play, was related to their ability to generate object substitution actions in an experimental setting.

4.2 Study 1

Study 1 sought to investigate whether children were able to generate object substitution actions without the help of an experimenter. In addition, children's understanding of an experimenter's intentions to pretend or perform a genuine action was investigated. The hypothesis was that children who saw an experimenter perform pretend actions during the first trials (model phase), and understood that it was the experimenter's intention to pretend, would generate their own novel pretend acts in the consecutive trials when no modelling occurred (extension phase). On the other hand, children who saw an experimenter perform trying actions during the first trials, and understood it was the experimenter's intention to do the correct action with the object, were expected to continue performing genuine actions with the objects in the consecutive trials. Finally, in order to find out whether explicit verbal cues would enhance children's generation and understanding of pretend actions (e.g., Rakoczy et al., 2006), we compared the responses of children who received these explicit cues (explicit group) to children who did not receive these cues (implicit group).

4.2.1 Method

4.2.1.1 Participants

Forty-five 3- and 4-year-olds (19 males, *mean age* = 44.7 months; *range* = 38 - 51 months; *SD* = 3.8 months) were randomly assigned to one of four groups: Implicit Pretending (12), Implicit Trying (11), Explicit Pretending (11), and Explicit Trying (11). Children were of similar ages across conditions. Most of the children were British and Caucasian. Eighty-six per cent of parents reported their education level. Parents had attained secondary education (17.8%), an undergraduate degree (24.4%), or a postgraduate degree (44.4%). Participants were recruited through local nurseries, the Glasgow Science Centre, the Edinburgh Zoo, and through posters and playgroups.

4.2.1.2 Materials

The apparatus consisted of 18 objects that were familiar to 3-year-olds. They were either daily used household objects (e.g., toothbrush, phone) or objects that were frequently used in children's play (e.g., drum, ball; see Appendix D, p. 171, for a full list of objects). Pictures of the object were also used. All objects were photographed against a white background. The photos were cropped and their brightness and contrast adjusted manually to decrease the influence of shadows (See Appendix E, p. 173, for the pictures of all objects). The colour pictures were printed in pairs on A4 sheets of paper and laminated. Two digital camcorders (SONY handycam) were used to record the responses of the child. One camcorder was placed just behind the experimenter to record the child's responses from the front. The other camcorder recorded the child's responses from the side.

4.2.1.3 Design

The study consisted of a 2 (Condition: Pretend, Trying) x 2 (Group: Explicit, Implicit) between-subjects design. All children (in both Implicit and Explicit groups) were given non-verbal cues to make the intentions of the experimenter clear. In the Pretend condition the non-verbal cues were: a positive facial expression, looking back and forth from the object to the child, and producing sound effects that were illustrative for the pretend object. In the Trying condition the non-verbal cues were: a confused facial expression, looking continuously at the object, and stating confusion by saying, "Hmmm?" In addition, in the Explicit group children were given clear verbal cues to state the goal/intention of the task (e.g., "Now can you pretend?" in the pretend condition, or "Now can you try and use it?" in the trying condition). In the Implicit condition, these verbal cues were not given.

The task consisted of two parts: 4 familiarization trials followed by 8 test trials. The familiarization trials were used to familiarize children with the task, and to check whether children could imitate object substitution actions (pretend action trials) as well as conventional uses of objects (real action trials). The test trials were divided into two phases: a model phase (4 trials), followed by an extension phase (4 trials), based on the design developed by Hoicka and Akhtar (2011) to test children's joke generation, and used by Bijvoet-van den Berg, Liszkowski, and Hoicka (see Chapter 3) to test children's generation of iconic gestures. The model phase allowed children to learn the rules of the game and it gave the opportunity to investigate children's understanding of the intentionality of pretend acts. The extension phase on the other hand investigated whether children could generate their own pretend acts without any help from others.

There were four possible orders in which the objects could be presented (see Appendix D, p. 171), and these were counterbalanced across all children.

4.2.1.4 Procedure

After a short warm-up, the child was sat opposite the experimenter at a small children's table. The experimenter placed a folder, containing all laminated A4 sheets with pictures, on the side of the table but within reach of the child. The experimenter placed a bag of toys, out of view from the child, next to her on the floor.

Familiarization Trials

The experimenter took out one of two objects (a toy car or a tub with a lid) and showed it to the child. She asked the child to name the object and showed a picture in the folder. In the real action trials the picture was identical to the object on the table, while in the pretend action trials the picture was different to the object on the table (e.g., picture of the tub when the car was on the table). In total, the familiarization part consisted of 4 trials (performing a real action and a pretend action with both objects). The real action was always performed first, followed by the pretend action, although it varied whether the car or tub actions were performed first.

The actions were identical for all children, but the verbal cues were different for the Implicit and Explicit Group (see Table 1a for an overview of the cues given to both groups). In the Implicit Group, the verbal cues given were identical in all 4 trials. The experimenter stated her intention to use the object like the picture in the folder, by saying "Let's use the [object] like this". She pointed at the object when saying the object's name and pointed at the picture in the folder when saying the word 'this'. The experimenter then used the object as if it was the object in the picture (e.g., driving the car around in circles on the table like a car in the real action trials, or 'driving' the tub around in circles on the table like a car in the pretend action trials). After that, she gave the object to the child and said, “Now you try!” During the child’s response the experimenter smiled at the child, irrespective of the action the child performed. She did not correct any incorrect actions and responded with “Alright!” after the child had played with the object for a few seconds. She then took back the object and turned over a page in the folder to present the next picture.

In the Explicit Group, the verbal cues given were different for the real and pretend action trials. In the real action trials, the experimenter stated her intention to use the object like the picture in the folder, by saying “Let’s try and use the [object] like this”. In the pretend action trials on the other hand, she said, “Let’s pretend that the [object] is this”. The actions performed were identical to the Implicit Group. After the experimenter performed the action, she reinforced her intentions by saying, “There!” in both the real and pretend trials. She then gave the object to the child and said, “Now you try!” The experimenter’s behaviour during the response of the child was identical to the Implicit Group.

Table 1a) Intentional verbal cues given in the familiarization trials, separately for the Explicit and the Implicit groups.

Implicit Group		Explicit Group	
Pretend action trials	Real action trials	Pretend action trials	Real action trials
Stating initial intention:			
“Let’s use the [object] like this”	“Let’s use the [object] like this”	“Let’s pretend that the [object] is this”	“Let’s try and use the [object] like this”
Reinforcing intention after action:			
No reinforcement	No reinforcement	“There!	“There!”
Prompting child to respond:			
“Now you try!”	“Now you try!”	“Now you try!”	“Now you try!”

Table 1b) Intentional verbal cues given in the test trials, separately for the Explicit and Implicit groups.

Implicit Group		Explicit Group	
Pretend Condition	Trying Condition	Pretend Condition	Trying Condition
Stating initial intention:			
“Let’s use the [object] like this”	“Let’s use the [object] like this”	“Let’s pretend that the [object] is this”	“Let’s try and use the [object] like this”
Reinforcing intention after action:			
“You see? I was using it like this”	“Whoops! I was not using it like this”	“There! You see? I was pretending it was this”	“Whoops! I did it wrong. I was not using it like this”
Prompting child to respond (Model Phase):			
“Now you try!”	“Now you try!”	Now can you try and pretend?”	“Can you try and use it?”
Prompting child to respond (Extension Phase):			
“Now you try!”	“Now you try!”	Now can you try and pretend? What could you pretend it is?”	“Can you try and use it? How would you use it?”

Test Trials: Model Phase

While children in the familiarization trials were presented with one object and one picture at the same time, during the test trials children were presented with one object and two pictures. One of the pictures was identical to the object on the table. The second was a picture of an object that was very different in function and shape from the object on the table. Different procedures were used for the Pretend and Trying conditions.

Pretend Condition. The Implicit and Explicit Group were again given different verbal cues (see Table 1b for an overview of the cues given to both groups). In the Implicit Group, the experimenter stated her intention to use the object like the picture that was different from the toy in her hand (target picture), by saying, “Let’s use the [object] like this”. When saying the word ‘this’ she pointed at the target picture. The experimenter then performed the action that one would perform with the toy in the target picture (e.g., using a ball as a cup), while making sound effects that were appropriate for the target object (e.g., making slurping sounds; see Appendix F, p. 174, for the actions and sound effects performed for each object). The experimenter performed the action twice, waiting 2 seconds between the actions while looking at the child with a positive facial expression (but not laughing). She reinforced her intention to pretend by saying, “You see? I was using it like this.” After that, she gave the object to the child and said, “Now you try!” The experimenter’s behaviour during the response of the child was identical to the familiarization trials.

In the Explicit Group, the experimenter stated her intention to use the object like the target picture by saying, “Let’s pretend that the [object] is this”. After performing the pretend action (identical to the Implicit Group), she reinforced her intention to pretend by saying, “There! You see? I was pretending it was this” and prompted the child to respond by saying, “Now can you try and pretend?”

Trying Condition. The Trying condition was identical to the Pretend Condition, except that the target picture to which the experimenter pointed when saying the word ‘this’ was the one identical to the object in her hand. Crucially, the experimenter performed exactly the same action as she did in the Pretend Condition (e.g., using the ball as a cup). However, instead of looking at the child with a positive facial expression during the action, she would look at the object with a confused facial expression and said, “Hmmm?” as if she did not understand what was going wrong.

In the Implicit Group, the experimenter stated her intentions by saying, “Let’s use the [object] like this”. After performing the wrong (trying) action she said, “Whoops! I was not using it like this. Now you try!” In the Explicit Group the experimenter started by saying, “Let’s try and use the [object] like this.” and responded to doing the wrong action by saying, “Whoops! I did it wrong. I was not using it like this. Can you try and use it?”

Test Trials: Extension Phase

The Extension trials were identical to the Model trials, except that the experimenter did not model any of the actions. After presenting the child with the object and the two pictures, the experimenter immediately asked the child to act upon the object. In the Implicit Group she said, “Now you try!” In the Explicit Group, she said in the Pretend Condition, “Now can you pretend? What could you pretend it is?” and in the Trying Condition, “Now can you try and use it? How would you use it?” Please note that the experimenter did not prompt the child as to how to use the object, i.e., she did not point to either picture.

4.2.1.5 Coding

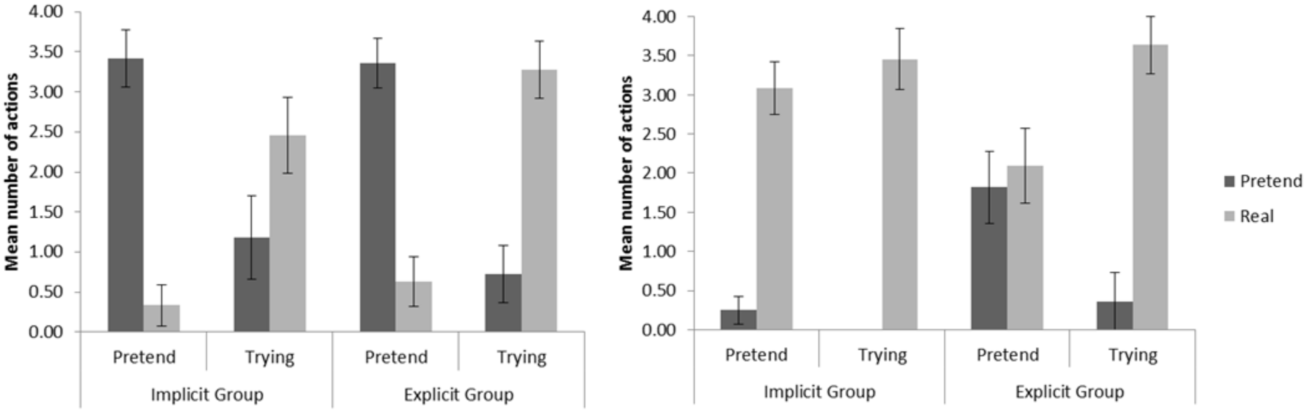
For each trial it was coded whether the child performed an action corresponding to the actual object (real response), an action corresponding to the object in the other picture (pretend response), or neither. For the Familiarization trials, children were divided into two groups: a group of children who responded correctly on all 4 trials, and a group of children who responded incorrectly on at least one of the trials. For the Model and Extension Phases the number of real responses and the number of pretend responses were calculated separately. For each child this resulted in a score for the number of pretend responses during both the Model Phase and Extension Phase, and the number of real responses for both the Model Phase and Extension Phase. All scores had a possible range from 0 to 4. Inter-rater agreement on 15% of the videos was very good (*Cohen’s kappa* = .822). In order to run a repeated-measures ANOVA, children were split according to age into a Young group and an Old group, using a median split (m*edian age* = 44 months).

4.2.2 Results

Following Rakoczy *et al.* (2004) and Rakoczy and Tomasello (2006), we computed difference scores. For both conditions (Pretend and Trying Condition) and for both phases (Model and Extension Phase), the number of real responses was subtracted from the number of pretend responses. This yielded a score from -4 to 4, with positive scores indicating that children mainly gave pretend responses, while negative scores indicated that children mainly gave real responses.

By calculating difference scores one should be aware that any information about the number of trials in which children responded with neither pretending nor real actions was lost. For example, a child that performed three pretend actions and one real action in the pretend condition would get a difference score of 2. However, a child that performed only two pretend actions and did not respond on the other two trials would also get a difference score of 2. In order to see how big a problem this might be for our sample, we checked how many children performed a real or pretend response on all trials. In the Model Phase, 88.9% of the children performed a real or pretend response on all trials, compared to 80% in the Extension Phase. This indicates that, although there are some children who performed other behaviours, the majority of children showed a pretend or real response on all trials. Therefore, we believed it was acceptable to continue using the difference scores.

Figure 1 displays the mean number of pretend and real responses performed during the Model Phase (Figure a) and the Extension Phase (Figure b), as a function of Group and Condition. A repeated-measures ANOVA was run, with Phase (Model, Extension) as a within-subjects variable, and Condition (Pretend, Trying) and Group (Implicit, Explicit) as between-subject factors. Initial analyses showed no effects of Age Group (all *F's* < .282, all *p's* > .585), Gender (all *F's* < 1.753, all *p's* > .193), nor whether children had performed successfully on all Familiarization trials or not (all F’s < 2.232, all p’s $> .143$). Therefore, they were taken out of the final analyses.



a) Model Phase

b) Extension Phase

Figure 1: Mean number of responses for which children pretended or performed a real response as a function of Group (Implicit/Explicit) and Condition (Pretend/Trying), separately for the Model Phase (figure a) and the Extension Phase (figure b).

Significant main effects of Condition, $F(1,41) = 31.159$, $p < .001$, $\eta_p^2 = .432$, and Phase, $F(1,41) = 63.717$, $p < .001$, $\eta_p^2 = .608$, were found. These main effects indicated that children performed overall more pretend responses in the Pretend Condition than in the Trying Condition, $t(43) = 5.533$, $p < .001$, $r = .645$, and more pretend responses in the Model Phase than in the Extension Phase, $t(44) = 6.570$, $p < .001$, $r = .704$. Furthermore, an interaction of Condition x Phase, $F(1,41) = 16.443$, $p < .001$, $\eta_p^2 = .286$, was found. To explore the difference in responses within this interaction, the difference scores from the Extension Phase were subtracted from the Model Phase to reveal the change in scores between Model and Extension Phase, separately for the Pretend Condition (mean change = 4.52) and the Trying condition (mean change = 1.45). The positive mean change in scores in both conditions indicated that for both the Pretend and Trying Conditions, children performed more pretend responses during the Model Phase than during the Extension Phase. However the change in scores from Model to Extension Phase was larger for the Pretend Condition than the Trying Condition, $t(42.120) = 3.827$, $p < .001$, $r = .508$. This suggests that children in the Trying condition were more likely to keep on performing real responses, while children in the Pretend Condition started to perform more real responses in the Extension Phase, compared to the Model Phase.

An interaction of Group x Phase was also found, $F(1,41) = 8.706$, $p = .005$, $\eta_p^2 = .175$. To explore the difference in responses within this interaction, similar change scores as above were calculated. Both change scores for the Implicit Group (mean change = 4.13) and the Explicit Group (mean change = 1.86) were positive, indicating that both groups gave more pretend responses in the Model Phase than the Extension Phase. However the change in scores from the Model to Extension Phase was larger for the Implicit Group than the Explicit Group, $t(40.560) = 2.640$, $p = .012$, $r = .383$. This suggests that the children in the Explicit Group were more likely to keep pretending in the Extension Phase than children in the Implicit Group.

4.2.2.1 Planned Comparisons

Planned comparisons were carried out to investigate the influence of explicit instructions on children's ability to distinguish intentions (Model Phase), and their ability to generate object substitution actions (Extension Phase). A 2(Group) x 2(Condition) ANOVA on the difference scores for the Model Phase revealed no main effect of Group, $F(1,41) = 1.222$, $p = .275$, $\eta_p^2 = .0.29$, and no interaction of Condition x Group, $F(1,41) = .387$, $p = .537$, $\eta_p^2 = .009$. Children were able to distinguish the intentions of the experimenter, both in the Implicit Group, $t(16.767) = 3.817$, $p = .001$, $r = .682$, and in the Explicit Group, $t(20) = 5.560$, $p < .001$, $r = .779$.

A 2(Group) x 2(Condition) ANOVA on the difference scores of the Extension Phase revealed a main effect of Group, $F(1,41) = 4.314$, $p = .044$, $\eta_p^2 = .095$, and a marginally significant interaction of Condition x Group, $F(1,41) = 3.246$, $p = .079$, $\eta_p^2 = .073$. Further analyses indicated that children in the Implicit Group did not generate more object substitution actions in the Pretend Condition compared to the Trying Condition, $t(21) = 1.001$, $p = .328$, $r = .213$. However, children in the Explicit Group did generate more object substitution in the Pretend Condition compared to the Trying Condition, $t(20) = 2.532$, $p = .020$, $r = .493$.

4.2.3 Discussion

4.2.3.1 Generation of object substitution actions

The results of Study 1 revealed that children generated more pretend actions in the Pretend Condition than in the Trying Condition. In the Extension Phase, when children had no model to respond to nor did they receive specific prompts, children generated their own object substitution actions when they understood it was the goal of the game to pretend, but only after receiving explicit instructions. Previous literature suggested that children were able to generate pretend actions around three years of age (e.g., Harris & Kavanaugh, 1993; Rakoczy & Tomasello, 2006). Our results extend previous literature by ruling out the possibility that the pretend actions of children were the result of imitation or prompts to do a specific action in order to perform a pretend action.

The explicit instructions to pretend or to try and use the object genuinely helped children to decide how to respond when they had no model to rely on (Extension Phase). Children gave more pretend responses when they were given explicit instructions to pretend than when they did not receive these instructions. This suggests that providing children with the direct association between the pretend action and the word ‘pretending’ in the Model Phase, helps children understand what to do in the Extension Phase. Rakoczy *et al.* (2006) found that children were more likely to give correct responses after receiving explicit training to pretend using auto symbolic play. Our results extend this literature and indicate that explicit instructions aid children's ability to generate object substitution actions as well.

4.2.3.2 Understanding the intentions behind object substitution

During the Model Phase, children differentiated between trials in which the experimenter showed the intention to pretend (Pretend Condition) in comparison to trials in which the experimenter showed the intention to do a genuine action (Trying Condition). Children corrected the mistakes an experimenter made, while imitating the pretend acts. These results resemble the findings of Rakoczy *et al.* (2004) on auto symbolic play, and extend previous literature indicating that children understand the intention to 'do wrong' when using object substitution.

However, children did not need explicit instructions to understand how to respond to the experimenter's behaviour in the Model Phase. Children who received explicit instructions to pretend or perform a genuine action responded equally well as children who did not receive those instructions. These results contradict the findings by Rakoczy *et al.* (2006) who found that children who received explicit instructions were also better at understanding the intentionality behind pretending. One possible reason why we did not find any differences is that the children in the Implicit Group were already responding according to ceiling level in the Pretend Condition. When looking at the mean number of actions in Figure 1a both Implicit and Explicit groups performed on average 3.5 pretend responses in the Model Phase. Therefore the explicit instructions might not have added anything to children's understanding of the intentionality of pretending.

Another possible explanation mentioned previously by Hoicka & Akhtar (2011) is that children responded differently to the two conditions based on the different emotion cues given rather than the underlying intentions. Children might have responded to the positive facial expression of the experimenter in the Pretend Condition by imitating her behaviour, while avoiding or correcting the actions associated with the frustrated, negative, facial expression in the Trying Condition.

4.3 Study 2

For Study 2 we were interested to find out what factors might influence children's ability to generate pretend acts. We hypothesized that children's divergent thinking skills would have an effect on their ability to generate new actions. Given that children with high divergent thinking skills are better at finding multiple uses for an object, these children were hypothesized to generate more pretend responses during the Extension Phase of the Pretend Condition than children with low divergent thinking skills.

Second, we expected children's inhibitory control to have an effect on children's responses in both the Model and Extension Phases of the experiment. The expectation was that children with low inhibitory control would find it difficult to inhibit the original action that belonged to the object. Therefore, we hypothesized that children with low inhibitory control would perform more real responses overall than children with high inhibitory control.

Third, we were interested to find out whether children's performance on the Pretend Experiment was related to the amount of children's object substitution during free play. We expected a positive relationship between the two. We were also interested to investigate the factors that might have an effect on children's object substitution during free play. It was hypothesized that divergent thinking skills and inhibitory control would be positively related to the amount of Object Substitution a child would display during the free play session.

4.3.1 Method

4.3.1.1 Participants

Thirty-four 3-year-olds (19 males, *mean age* = 42 months; *range* = 36 - 48 months; *SD* = 3.8 months) participated. One child (female, 42 months) was unresponsive during the free play session and therefore excluded from analyses involving free play. Most children were British and Caucasian. Fifty-three per cent of parents reported their education level. Parents had attained secondary education (11.8%), an undergraduate degree (17.6%), or a postgraduate degree (23.5%). Participants were recruited as in Study 1.

4.3.1.2 Measures

Pretend experiment

The materials, procedure and coding of the pretend experiment were identical to Study 1. Two digital video camcorders (SONY Handycam) were used to record the behaviour of the child during all tasks. Cameras were placed as in Study 1.

Unusual Box Test (Divergent Thinking)

Divergent thinking was assessed using the Unusual Box Test. The materials and procedure used for the Unusual Box test are described in Bijvoet-van den Berg and Hoicka (see Chapter 2). The child was presented with the Unusual Box, a wooden box with an open top containing several different features (e.g., rings, stairs, hole), which was placed on a turn table. The experimenter showed all the features on the box while turning the box. After the child was given a chance to turn the box as well, the experimenter gave the child the first out of five novel objects (egg holder, spatula, feather roller, Kong rubber toy, and hook). The child was given 90 seconds to play with the object, after which s/he was given a new object to play with. The experimenter sat on the side and interacted minimally with the child.

The behaviour of the child was coded for all five trials. Each trial started the moment the child took the object from the experimenter and lasted 90 seconds. Divergent thinking scores were calculated by counting the number of different actions that the child performed for all trials combined (5 x 90 seconds). Actions were recorded on two features: what type of action was performed (e.g., hit, place) and what part of the box was used during the action (e.g., stairs, rings). One action might be rolling one of the objects on the stairs. Another action might be hitting the side of the box with one of the objects. Actions performed with only the box or object, using hands to manipulate either, were also counted as actions. Performance of the same action with different objects was counted as the same action. Children were divided into a Low and High Divergent Thinking group using a median split (*median score* = 25).

Day-Night task (Inhibitory Control)

Inhibitory control was assessed using the Day-Night task (Gerstadt, Hong, & Diamond, 1994). Fourteen laminated A5 pictures were used. Half of them showed a cartoon drawing of a yellow sun on a light blue background. The other half showed a white moon and four stars on a black background. The experimenter started with two practice trials in which she explained the rules of the game, namely that when presented with a moon card the child had to respond with the word ‘day’. On the other hand, when presented with a sun card the child had to respond with the word ‘night’. Two practice trials were given in which the experimenter presented a sun and a moon card. If the child responded incorrectly, the experimenter would explain the rules again and give another two practice trials. After that, 14 test trials (7 sun cards and 7 moon cards) were presented to the child in a pseudorandom order (for the exact order, see Gerstadt *et al*., 1994). The experimenter always asked, “What do you say for this one?” but no other feedback was given.

The child's answers were written down by the experimenter during the task, and afterwards coded for being correct or incorrect. A correct answer was when a child said 'day' when presented with a moon card, and 'night' when presented with a sun card. Any other responses were counted as incorrect. Children were divided into a Low and High Inhibitory Control group using a median split (*median score* = 8).

Free Play

For the free play task, the child was told that the experimenter was interested in seeing how well s/he could play on his/her own. This was to inhibit the child's desire to play together with the experimenter. The experimenter sat on a table at the side (approx. 2 meters away) and acted busy. Thirty-six toys (or toy parts) were used, divided equally over three sessions of free play. Half of the toys were of indiscriminate shape and function whereas the other half were functionally specific. The toys of indiscriminate shape and function were included to allow for object substitution. Figure 2 displays the toys used for each session. The toys were presented to the child on a plastic tray (approx. 30x40cm).

The child was given up to 5 minutes to play with the toys, with a minimum play time of 2 minutes. If the child clearly stated after 2 minutes that s/he was finished playing with the toys, the experimenter would take the tray with the toys away and replaced the toys with new ones. During the task, some children found it hard to play on their own and were constantly trying to interact with the experimenter or parent by going up to them and thereby moving out of view of the camera. To avoid that play behaviour was not observable in these cases, the experimenter moved closer to the child so that the child would stay seated at the table (this was the case for 3 children). The experimenter still acted busy and avoided interacting with the child.

The child's behaviour during the free play sessions was coded using The Observer XT. Each session started when the experimenter placed the tray with toys on the table and removed her hands from the tray. A hierarchical system was used to code the child's behaviour, based on the Exploratory Behavior Scale (EBS) by Van Schijndel, Franse, and Raijmakers (2012). Similar to the EBS, the lowest behaviour level was *passive contact*, followed by *active manipulation*. For the purpose of this study, the highest level of the EBS (exploratory behaviour) was replaced by the behaviour level *clear pretending.* A distinction was made between auto symbolic pretend play, in which the child used the object for its original purpose in a pretend-like fashion (e.g., pretending to pour tea from a teapot); and object substitution, in which a child pretended that an object was something else (e.g., pretending that a stick was a spoon). Behaviour that seemed to be pretend behaviour, but could not be conclusively coded as such was not considered clear pretending and left out of the analyses. Appendix G (p. 177) gives a short description of the levels in the correct hierarchical order, and examples of children's behaviour. The child's behaviour was coded during 5 second intervals. The length of the intervals was determined on the basis of the approximate time it took children to execute pretend behaviour during the free play sessions. Following Van Schijndel, Franse, and Raijmakers (2012), the highest level of behaviour that a child demonstrated per time interval was coded. For example, when within one interval a child actively manipulated and clearly pretended with an object, that interval was coded as clear pretending. A maximum number of 180 intervals were coded (60 intervals per session x 3 sessions). The frequency of intervals that children spent in active manipulation, auto symbolic play, and object substitution were used for analyses[1].

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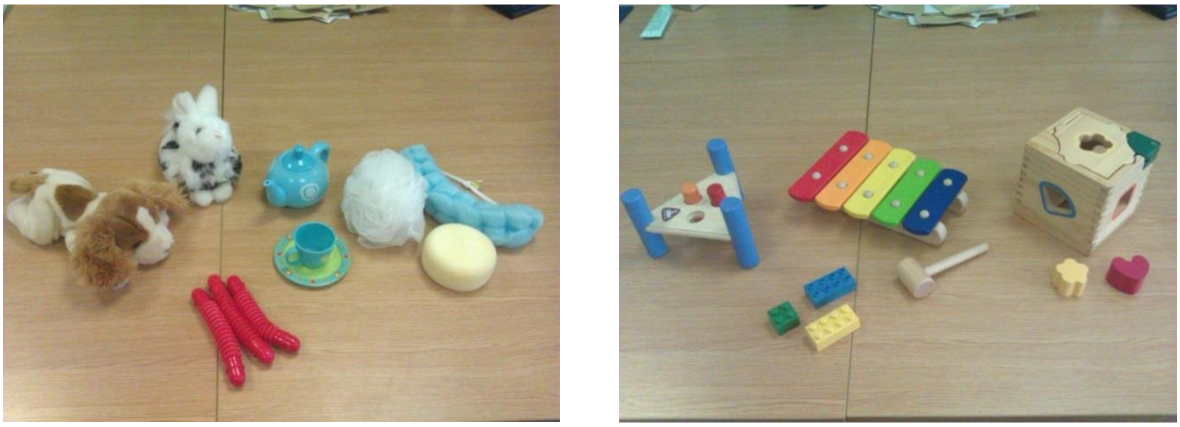
[1] Not all children completed 180 intervals (N = 10). When children clearly stated they were finished



A) Pretend Session

B) Functional Session

C) Combined Session

Figure 2: Toys used for the three sessions of free play. A) Pretend session – Functionally specific toys: stuffed toy animal dog and rabbit, teapot with lid, cup and saucer. Indiscriminate function toys: three sponges of different shapes, three closed-off tubes with ridges. B) Functional session - Functionally specific toys: xylophone, hammer, shape sorter with lid, two blocks (heart and flower shape) that fit in the shape sorter. Indiscriminate function toys: two round shaped pegs and a block to place them in, three Duplo blocks. C) Combined session – Functionally specific toys: bucket, shovel, fish-shaped sand shaper, two miniature plastic dolls (a lady and a little girl). Indiscriminate function toys: shoe lace, three plastic cotton reels, three wooden blocks of different shapes (rectangle, round and rainbow shape).

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playing, the session was stopped. Initially, we controlled for the variance in number of intervals by dividing the frequency of behavior by the total number of play intervals. However, no differences in analyses were found when using this measure. Therefore, for simplicity, we continued using frequency instead of relative frequencies.

4.3.1.3 Design

This study was a within-subjects design in which each child completed all tasks. Unlike the pretend experiment in Study 1, children completed both the Trying and Pretend conditions, but on different days. For the 21 children who participated in their nursery, the tasks were administered in four sessions (the Day-Night task was administered together with one of the other tasks). The other 13 children completed the tasks in two sessions, for convenience of the parents who brought the children to the lab. The 4 counterbalanced testing orders are shown in Table 2. The Pretend condition was deliberately not combined with the free play session or the Trying condition, to avoid that the child's behaviour in the pretend condition would influence his/her behaviour on the other tasks or vice versa.

The orders of the objects used for the pretend experiment are displayed in Appendix D (p. 171). Children were never presented with the same objects in the Pretend and Trying conditions. When order 1 was presented to the child in the Pretend condition, they received order 4 in the Trying condition, or vice versa. Similarly, when order 2 was presented in the Pretend condition, they received order 3 in the Trying condition, or vice versa. For the Unusual Box test, the order of objects given to children was counterbalanced, following Bijvoet-van den Berg & Hoicka (see Chapter 2). For the free play session, the toys were given in three possible orders (Order 1: Pretend (P) – Functional (F) – Combined (C); Order 2: F – C – P; Order 3: C – P – F), which were counterbalanced across children.

Table 2: Order of tasks in Study 2; children who came into the lab with their parents performed the first tasks (above the line) during the first session and the other tasks (below the line) during the second session. Children who participated in their nursery performed all tasks on separate occasions. The Day-Night task was administered during the same session as another task.

Order 1	Order 2	Order 3	Order 4
Pretend Condition	Unusual Box Test	Free Play	Trying Condition
Unusual Box Test	Pretend Condition	Trying Condition	Free Play
Day-Night task	Day-Night task	---	----
----	---	Unusual Box Test	Pretend Condition
Trying Condition	Free Play	Pretend Condition	Unusual Box Test
Free Play	Trying Condition	Day-Night task	Day-Night task

4.3.2 Results

4.3.2.1 Pretend Experiment

Figure 3 displays the mean number of pretend and real responses as a function of Condition and Phase. For the statistical analysis, we again calculated difference scores similar to the analysis in Study 1. For each child, for both conditions (Pretend and Trying Condition) and for both phases (Model and Extension Phase), the number of real responses was subtracted from the number of pretend responses. This yielded a score from -4 to 4, with positive scores indicating that children mainly performed pretend responses, while negative scores indicated that children mainly performed real responses.

A 2 (Condition) x 2 (Phase) repeated-measures ANOVA was run, with Inhibitory Control (High, Low) as a between-subject factor. Initial analyses showed no effects of Age Group (*median age* = 42 months; all *F's* < 3.095, all *p's* > .088) or Gender (all *F's* < 1.633, all *p's* > .210), therefore they were taken out of the final analyses.

A significant main effect of Condition was found, $F(1,31) = 45.262$, $p < .001$, $\eta_p^2 = .594$, with children performing more pretend responses in the Pretend Condition (mean difference score = .60) than in the Trying Condition (mean difference score = -2.46; $t(33) = 6.750$, $p < .001$, $r = .762$). Furthermore, a significant main effect of Phase, $F(1,31) = 38.750$, $p < .001$, $\eta_p^2 = .556$, indicated that children performed more pretend responses in the Model Phase (mean difference score = .32) than in the Extension Phase (mean difference score = -2.18; $t(33) = 6.579$, $p < .001$, $r = .753$). The analysis revealed no interaction effects, nor any effects of Inhibitory Control (all *F's* < .624, all *p's* > .436).

4.3.2.2 Planned Comparisons

Planned comparisons were carried out to investigate children's ability to distinguish between intentions (Model Phase) and their ability to generate object substitution actions (Extension Phase). Repeated-measures ANOVA (comparing Pretend and Trying conditions) on the difference scores for the Model Phase revealed a main effect of Condition, $F(1,33) = 40.165$, $p < .001$, $\eta_p^2 = .549$. This indicated that children distinguished the intentions of the experimenter such that they performed more pretend actions during the Pretend Condition (*mean difference score* = 2.06) compared to the Trying Condition (*mean difference score* = -1.41), $t(33) = 6.338$, $p < .001$, $r = .741$.

Repeated-measures ANOVA on the difference scores of the Extension Phase revealed a main effect of Condition, $F(1,33) = 20.811$, $p < .001$, $\eta_p^2 = .387$. Children were found to generate more object substitution actions in the Pretend Condition (*mean difference score* = -.85) compared to the Trying Condition (*mean difference score* = -3.50), $t(33) = 4.562$, $p < .001$, $r = .622$.

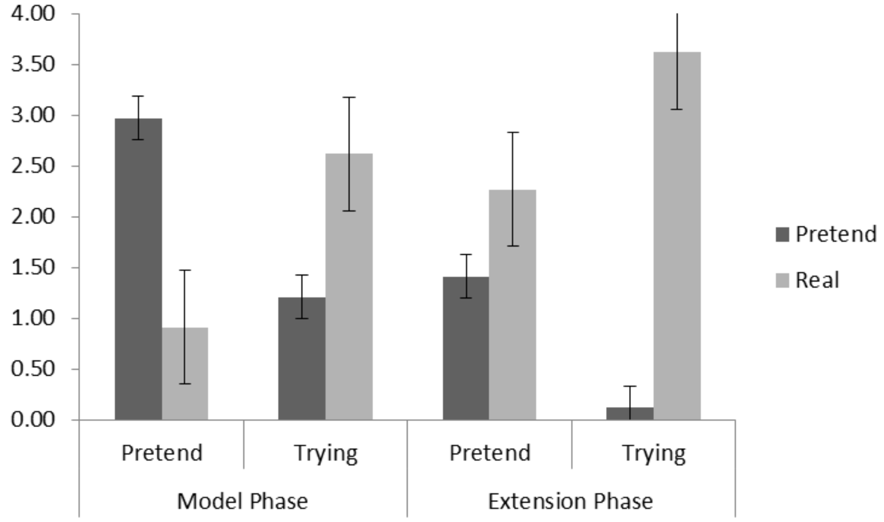

Figure 3: Mean number of responses for which children pretended or performed a real response as a function of Condition (Pretend/Trying) and Phase (Model/Extension).

4.3.2.3 Generating pretend actions, divergent thinking, and inhibitory control

We further investigated whether children's ability to generate pretend acts in the Extension Phase of the Pretend Condition was related to Divergent Thinking, Inhibitory Control, the number of intervals during free play in which children performed Object Substitution or Auto Symbolic pretend play, and the number of intervals in which they performed Active Manipulation. For this analysis, children were split into two groups based on whether children had performed at least one pretend response (N =19) during the Extension Phase of the Pretend Condition or not (N = 15). The same procedure was used to divide children who performed Object Substitution during at least one interval (N = 17) and children who never performed Object Substitution during free play (N = 16). Table 3 shows the results for each variable. None of these variables were related to children's ability to generate pretend acts.

Table 3: Analyses for the relationship between children's ability to generate object substitution actions during the extension phase of the pretend condition and divergent thinking, inhibitory control, frequency of object substitution, auto symbolic pretending, and active manipulation during free play, age, and gender.

Variable	*Mean Difference*[1]	t	χ^2	*Df*	p
Divergent Thinking	-.544	.255		32	.801
Inhibitory Control			.022	1	.881
Free Play (N = 33)					
Object Substitution			.259	1	.611
Auto Symbolic Pretending	-3.33	.914		31	.368
Active Manipulation	13.60	1.667		31	.106
Age	.242	.183		32	.856
Gender			1.266	1	.260

[1] Positive mean difference scores indicate higher scores for children who did generate object substitution actions

4.3.2.4 Free play, divergent thinking, and inhibitory control

Table 4 shows the results for the differences in divergent thinking, inhibitory control, age and gender between children who performed object substitution during at least one interval and children who never performed object substitution. No differences were found in any of these variables. Exploratory analyses were performed for those children who performed Object Substitution during at least one interval (N = 17; 10 males; *mean age* = 42 months; *range* = 36 – 48 months; *SD* = 4.2 months). In this subset, the number of intervals in which children performed Object Substitution was positively correlated to the originality scores of the Unusual Box test (Spearman's r = 0.487, p = 0.047). This indicates that children who generated more original novel actions also performed more Object Substitution actions. No significant correlations were found between the number of intervals in which children performed Objects substitution actions and the fluency scores of the Unusual Box test (Spearman's r = 0.411, p = 0.101), nor inhibitory control (Spearman's r = 0.090, p = 0.731).

Table 4: Analyses for the relationship between children's generation of object substitution during free play and divergent thinking, inhibitory control, frequency of object substitution, auto symbolic pretending, and active manipulation during free play, age, and gender.

Variable	*Mean Difference*[1]	*t*	χ^2	*Df*	*p*
Divergent Thinking	2.588	1.267		31	.215
Inhibitory Control			.000	30	.982
Age	.320	.236		31	.815
Gender			.022	1	.881

[1] Positive mean difference scores indicate higher scores for children who did generate object substitution actions

4.3.3 Discussion

Study 2 replicated the results found in the Explicit Group of Study 1. Children overall produced more pretend actions in the Pretend Condition than in the Trying condition, and generated their own object substitution actions when they understood it was the goal of the game to pretend. Children also distinguished the intentions of the experimenter between the Pretend and Trying conditions.

Children's divergent thinking skills and inhibitory skills were not related to their ability to generate object substitution actions during the pretend experiment, nor to the amount of object substitution they performed during free play. These results contradict previous literature reporting a relationship between pretend play behaviour and divergent thinking (e.g., Russ *et al.*, 1999; Wyver & Spence, 1999), as well as between pretend play behaviour and inhibitory control (Kelly *et al.*, 2011). Exploratory analyses did show that of the children who performed object substitution actions during free play the amount of object substitution they used in their play was positively correlated to the originality scores of divergent thinking. This suggests that children who are able to come up with more original actions using divergent thinking might also be more likely to use objects in more original ways by using object substitution during free play. Future research is needed to further investigate this relationship.

It is interesting to note that out of the children who did not generate any object substitution actions in the pretend experiment, still half of these children showed object substitution during free play. Similarly, out of the children who did generate any object substitution during the pretend experiment, still half of the children did not generate object substitution actions during free play. This indicates that children's inability to generate object substitution actions in an experimental settings does not necessarily mean that they do not show object substitution in a free play setting, or vice versa.

4.4. General Discussion

4.4.1 Generation of Object Substitution actions

The two studies described in this paper showed children's ability to generate object substitution actions without the use of a model or specific prompts. The results from both studies dismiss the possibility that children's pretend responses were caused by imitating the experimenter (e.g., Harris & Kavanaugh, 1993; Wyman, Rakoczy, & Tomasello, 2009) or through prompting a specific pretend action (e.g., Harris & Kavanaugh, 1993; Rakoczy, Tomasello, & Striano, 2004; Rakoczy & Tomasello, 2006). By performing the action of the target picture, 3-year-olds displayed their understanding of the representational nature of pretence. This means that they understood that they can use an object 'as if' it is something else.

Our findings provide a better understanding of the cognitive abilities of children when engaged in pretend play. While previous experimental research suggested that children understood the intentions behind other's pretend play (Rakoczy, Tomasello, & Striano, 2004; Rakoczy & Tomasello, 2006) and could respond to an experimenter's pretend actions by also pretending (e.g., Harris & Kavanaugh, 1992; Rakoczy, Tomasello, & Striano, 2004), this research indicates that children can generate pretend actions in the same way as adults do, that is by representing an object as something else and using the object in that way.

When children were shown pretend actions in the Model Phase (Pretend Condition), they were also more likely to generate object substitution actions in the Extension Phase. This is in line with the finding by Nielsen and Christie (2008) that adult modelling facilitates children's production of object substitution actions. In this study children played with a dollhouse and different toys: small dolls, toy items that were placed in the dollhouse (e.g., bed, couch), replica objects (e.g., toy hamburger, toy soft drink), and miscellaneous functional items (e.g., string, piece of cloth). After a short 4-minute free play session, the experimenter modelled three play scenarios in the dollhouse, all of which contained object substitution with one of the miscellaneous functional items (e.g., using the piece of cloth as a towel). After modelling children were allowed another 4-minute free play. Children performed on average more pretend actions in the post-modelling phase compared to the pre-modelling phase. Furthermore, around half of the actions performed were imitated from the experimenter, while the other half were novel object substitution actions. Their explanation for children's novel action production was that children might have used the modelled acts of pretence as a foundation for the generation of their own pretend actions. In our experiment this seems an improbable explanation since the objects presented in the Extension Phase were unrelated to previously presented objects. Therefore it is unlikely that the previously performed actions could have guided children's generation of novel pretend actions.

An alternative explanation to children's increased generation of pretend actions is that instead of extending the use of the same pretend actions, they extended the higher intention or goal of the game which was to pretend in the Pretend Condition, while performing a genuine action in the Trying Condition. This idea converges with findings that children create novel jokes after an experimenter modelled joking actions (Hoicka & Akhtar, 2011), or generating novel iconic gestures after being shown models of iconic gestures on distinct objects (Bijvoet-van den Berg, Liszkowski, & Hoicka, Chapter 3). In all these studies, children take into account the higher-order goal of the game (i.e., to generate pretend actions, jokes, or iconic gestures) and apply this goal to new situations.

The finding that children performed on average more pretend actions during the Model Phase compared to the Extension Phase suggests that children find it easier to produce object substitution actions after someone else modelled the action than when they have to generate these actions on their own. This is congruent with previous findings that children produce more pretend actions after being shown a pretend model (e.g., Fiese, 1990; Rakoczy, Tomasello, & Striano, 2006). One possible explanation is that responding to someone else's pretend actions by imitating the same action requires fewer cognitive skills than when children have to think of their own object substitution action. In addition, pretend play is often a social encounter (Shim, Herwig, & Shelly, 2001). Therefore, children might find it easier to affiliate with someone else who is pretending and engage in pretend play than when they have to generate these actions without someone else joining in.

4.4.2 Understanding intentions behind object substitution actions

Both naturalistic and experimental research has focused on the question as to whether children understand that, while pretending, adults are intentionally performing a 'wrong' action. In a naturalistic setting parents were found to give specific cues to indicate they were pretending (e.g., exaggerated movements, sound effects; Lillard, 2006). When in an experimental setting experimenters used similar cues to indicate their intention to pretend, 3-year-olds distinguished between auto symbolic pretend actions (e.g., writing with a pen that has the cap still on) and trying actions (when the experimenter intended to do a genuine action; Rakoczy, Tomasello, & Striano, 2004).

The present studies indicate that 3-year-olds understand the intentions behind object substitution actions as well, and that they differentiate these intentions from the intention to do a genuine action (but accidentally performing a wrong action). Our results resembled the findings by Rakoczy, Tomasello, and Striano (2004), suggesting that children are good at understanding the intentions behind both auto symbolic play and object substitution. The extra difficulty of having to suppress the initial motor response during object substitution does not seem to expunge children's ability to understand intentions behind pretend play.

4.4.3 Divergent thinking

The ability to think of multiple uses for an object (divergent thinking) seemed to have no effect on how good children were in generating object substitution actions. One possible reason for this is that we gave children a specific target picture to use as their pretend object. Therefore, children were limited in what they could pretend the object in hand would be. So in a way divergent thinking skills were not necessarily required for generating the pretend action. This could explain why we did not find a relationship between pretend play and divergent thinking while other studies, which investigated children's imagination skills (Russ *et al.*, 1999) or the ability to use themes in their pretend play that are remote from those encountered by the child in his/her everyday live (Wyver & Spence, 1999), did.

We also found no relationship between divergent thinking skills and how much pretend play children displayed during free play. Because children were not restricted to generate specific object substitution actions during free play, they were not constrained in their use of divergent thinking as compared to the pretend experiment. However, it might be that the incidences of object substitution found during free play did not necessarily require elaborate divergent thinking skills. When looking at the types of object substitution actions performed, on most occasions the object being substituted resembled the pretend object in shape or function. For example, the red bendy stick was often used to represent a spoon to stir with. On another occasion, children pretended that the blue sponge was a catapult, which, given the elastic qualities of the sponge, was not a difficult association. Therefore, it is possible that the object substitution actions performed during free play did not necessarily require divergent thinking skills, hence no relationship between divergent thinking and object substitution during free play was found.

The finding that divergent thinking might be related to some forms of pretending (e.g., imagination, thematic play) while not to other forms (e.g., object substitution) suggests that not all pretend play necessarily requires divergent thinking. For example, in studies that did find a relationship between pretend play and divergent thinking (e.g., Russ *et al.*, 1999; Wyver & Spence, 1999), children's pretend play was not restricted to using objects but could be based on what children were saying or doing (e.g., pretending to fly a spaceship). It may be that the use of objects decreases the need for divergent thinking because the shape and form of the object already offered children a framework to build their pretend play on.

Future research could focus on what specific qualities of pretend play scenarios are enhanced by children's divergent thinking skills. The relationship between divergent thinking and the ability to generate object substitution actions could be further investigated by giving children multiple options for how they could substitute the object (e.g., presenting multiple pictures). Regarding naturalistic research, it might be a good idea to observe children's behaviour when all the objects are of indiscriminate function. The fact that half of the objects were functionally specific might have guided children in a certain direction that led to the small variation in the type of object substitution actions. When none of the objects have a prescribed function, children's divergent thinking skills might indeed be of influence to children's ability to generate object substitution.

4.4.4 Inhibitory Control

Inhibitory control was found to have no effect on children's ability to generate object substitution actions, either in an experimental or naturalistic settings. This seems counterintuitive, given that the main skill to object substitution seems to be to inhibit the original use of the object in order to do the action of the target object. It also contradicts previous findings that inhibitory control is related to children's symbolic play skills (Kelly *et al.*, 2011).

Gerstadt *et al.* (1992) mentioned in their discussion that the Day-Night task might not be suitable for 3-year-olds. In their study a large number of children failed the practice trials, in which children did not respond correctly to the cards even right after specific instructions as to what to say were given. They suggested that children's inhibitory control was so low that even when told specifically what to say they found it hard to inhibit the initial response. Indeed, we also found that half of the children in our sample did not respond correctly on all practice trials. This suggests that the Day-Night task might not have been an appropriate test to assess inhibitory control in 3-year-olds.

The Day-Night task was chosen for this study because it requires a child to inhibit an initial response in order to give an alternative response. Alternative measures of inhibitory control in young children include assessing children's ability to inhibit the urge to peek when an experimenter is wrapping a gift for the child (Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996), or respond to the instructions of one character while inhibiting the instructions of another (Bear-Dragon task, Reed, Pien, & Rothbart, 1984). However, these measures only require a child to inhibit a response but they do not require a child to give an alternative response (i.e., the correct response is no response). Therefore, the Day-Night task was thought to be more suitable to compare to children's ability to generate object substitution actions. Future research could investigate whether children's ability to generate object substitution actions is related to other measures of inhibitory control.

4.4.5 Experimental vs. Naturalistic setting

Our results indicate that children's ability to generate actions in an experimental setting do not relate to their pretend behaviour in a naturalistic setting. Half of the children who successfully generated object substitution actions in the pretend experiment performed no such actions during free play. In contrast, half of the children who did not generate any object substitution actions in the pretend experiment did perform this type of actions during free play. This contradicts the findings by Kelly *et al.* (2011) who did find a positive relationship between experimental and naturalistic pretend play. However, in the Kelly *et al.* study the free play session always followed the experimental task. It could therefore be that children were more focused on pretend play because it was stimulated in the previous task which in return might have caused children to generate more pretend play than what they would normally do.

The most logical explanation for our findings is that when children are able to generate object substitution actions in an experimental setting, this does not necessarily mean that they will display this ability in their free play. On the other hand, children's responses in an experimental setting might not reflect their full ability to display certain behaviour, given that we found that children did show object substitution in the free play setting while they did not show such behaviour in the pretend experiment. Although it is hard to find a solution for this phenomenon, it is important to be aware of it, especially when working with young children. These results further suggest we should be careful to interpret findings from experiments as being reflective as to how children would respond in a naturalistic setting. Future studies should take into account the possible discrepancy between experimental and naturalistic behaviour and attempt to conduct more studies in which experimental and naturalistic behaviour are directly compared.

4.4.6 Conclusion

The results from these studies suggest that 3-year-olds are able to generate their own object substitution actions. They do not require a model or specific prompts from an experimenter to do so. Explicit instructions that emphasize the goal to pretend or try to perform genuine actions further aids children’s ability to generate object substitution actions. In addition, children differentiate between an experimenter’s intentions to pretend or to try and perform a genuine action. However, children’s ability to generate object substitution actions was not related to their divergent thinking skills, inhibitory control, nor how much they displayed object substitution during free play.

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Chapter 5

General Discussion

5.1 Summary of Findings

The aim of this thesis was to gain information about children’s ability to generate actions without getting input from others. Three different settings were chosen to offer a varied investigation of children’s ability to generate actions: (1) generating multiple actions with novel objects, (2) generating iconic gestures in order to communicate, and (3) generating pretend actions using object substitution. Before discussing the findings more generally and the implications of these findings for the broader field, the results of each chapter are briefly summarized.

5.1.1 Generating multiple actions with novel objects (Chapter 2)

In order to assess children’s ability to generate multiple actions with novel objects, the Unusual Box test was developed. As the Unusual Box test assessed children’s ability to think beyond one action and search for multiple possibilities to use an object, the test was argued to measure divergent thinking as well. Study 1 assessed the validity of the Unusual Box test as a measure of divergent thinking, and individual differences in the number of actions performed (fluency) in 3- and 4-year-olds. The fluency scores on the Unusual Box test were positively correlated to two existing measures of divergent thinking, i.e. the Instances subtest of the Wallach and Kogan tests of creativity (Wallach & Kogan, 1965) and Thinking Creatively in Action and Movement (TCAM; Torrance, 1981). Therefore, the Unusual Box test was argued to be a valid measure of divergent thinking. A range of fluency scores was found (8 – 34 actions) indicating individual differences in children’s ability to generate multiple actions with novel objects.

Study 2 assessed the test-retest reliability of the Unusual Box test, as well as the chance to use this test in children younger than 3 years. Sixteen 2-year-olds were assessed twice two weeks apart on the Unusual Box test. A strong positive correlation was found between children’s fluency scores on the two assessments, indicating high test-retest reliability. Individual differences in fluency scores (10-32 actions) and the absence of a floor effect indicated that the Unusual Box test is usable in children as young as 2 years of age. When the data of both studies were combined, a positive correlation between age and fluency scores was found, indicating that children get better at generating multiple actions with increasing age.

5.1.2 Generating iconic gestures in order to communicate (Chapter 3)

Children’s ability to generate iconic gestures without the help of others was assessed using a game to request stickers from an experimenter. In order to get a sticker children had to communicate to the experimenter which out of two objects they wanted (only one object had a sticker attached to it). Children were not able to communicate through speech because the experimenter was wearing headphones, nor through pointing because the two objects were placed close together. A correct iconic gesture required the child to create a gesture that represented the object requested, in such a way that the experimenter could distinguish which of the two objects the child desired. Children generated a correct iconic gesture on 71% of the trials. The odds ratio indicated that children were 37 times more likely to generate a correct gesture than to give any other type of response. These findings indicate that children are indeed able to generate their own iconic gestures in order to communicate; and that they understand the representational nature of iconic gestures, and use this in their own generation of iconic gestures.

5.1.3 Generating pretend actions using object substitution (Chapter 4)

Previous studies on children's ability to generate pretend actions are limited in that they cannot rule out the possibility that children used imitation or specific prompts to guide their pretend behaviour. Study 1 showed that 3- and 4-year-olds are indeed able to generate object substitution actions without the help of others. In addition, children distinguished between the intentions of an experimenter when showing object substitution actions, in which the experimenter had the intention to do a 'wrong' action; or showing trying actions, in which the experimenter had the intention to do a genuine action. Children mainly imitated the experimenter after object substitution actions, while correcting the trying actions. When the experimenter no longer modelled an action, children were more likely to generate novel object substitution actions after pretend trials than after trying trials. Children did require explicit instructions to pretend (e.g., "Now can you pretend?") before they were able to generate these novel object substitution actions. However, these instructions did not include giving children specific prompts as to which pretend actions they should perform.

Study 2 further investigated the influence of divergent thinking and inhibitory control on the ability to generate object substitution actions. For both factors no relationship was found with children's ability to generate object substitution actions in an experimental setting, nor with the amount of object substitution shown in a free play setting. In addition, children's responses during the experiment and the free play setting were unrelated. This suggests that divergent thinking and inhibitory control might not be required for all types of pretend play, and that one must be cautious to interpret experimental results as reflective of children's behaviour in naturalistic settings.

5.2 Generation of novel actions

5.2.1 Creating variation

Our findings indicate that children are able to generate novel actions from an early age. They were shown to generate actions with novel objects from 2 years, novel pretend actions from 3 years, and novel iconic gestures from 3.5 years. No floor effects were found in any of these studies indicating that children in all the age groups that were studied were able to generate these novel actions. Therefore, it is possible that even younger children are able to generate novel actions. Future research should replicate these findings in younger age groups and aim to establish when children start to generate their own actions.

The findings endorse the idea that children are not restricted to imitating the behaviour of others (social learning) but also use their own exploration skills and knowledge to generate actions. It also suggests that the ability to create variation is already available at a very young age. This is an interesting finding because it validates ideas from cultural evolution theory, that the ability to generate variation is an important ability for the survival of our species (Mesoudi, Whiten, & Laland, 2004). Further research on even younger children and comparative research with primates could give us a more decisive indication as to whether the ability to generate variation is innate and/or whether certain environmental factors play a role in children’s ability to generate variation.

Social learning and individual learning are both argued to be important for the evolution of our knowledge, ideas, and technology; also known as cultural traits (Mesoudi *et al*., 2004). The experimental designs in Chapter 3 and 4 used a combination of social and individual learning to show children’s ability to generate novel actions. Social learning through modelling was thought to be the best way to make children familiar with the task and to show them the goal of the study without telling them specifically what to do. It was found that children indeed generated novel representational actions after similar actions were modelled by an adult. This finding provides an interesting opportunity for both parents and teachers if they want to encourage children to practice their representational skills. The procedures used in Chapter 3 to model iconic gestures and Chapter 4 to model object substitution actions could form a basis for developing a game-like structure to practice these skills.

Unlike other studies which investigated children's ability to generate representational actions (e.g., Harris & Kavanaugh, 1993; Rakoczy, Tomasello, & Striano, 2004; Rakoczy & Tomasello, 2006), we never reinforced correct responses or discouraged incorrect responses. Therefore, the information gained from social learning was completely child-driven. Our results showed that children learned the goal of the task through social learning. In addition, they were able to extend this goal to consecutive trials, thereby using what they learned through social learning to generate their own novel actions. This reinforces the ideas posed by social learning theories, such as Vygotsky's dialectical theory (Vygotsky, 1934) and pedagogy theory (Csibra and Gergely, 2006), that children learn new things through the observation of other people's behaviour. In addition, the results in Chapter 4 showed that children were more likely to generate novel actions when given explicit instructions to do so. This further suggests that social interaction can help children to generate new behaviours.

Our findings demonstrate how social and individual learning can be used in combination to generate novel actions. The same is likely the case for creating variation in cultural traits. Social learning is thought to provide children with a working platform on which they can build their individual exploration and generation of novel actions. This is in line with Piaget's theory of cognitive development (Piaget, 1952) and the experiential learning theory (Kolb, 1984), which pose that ideas are formed and transformed based on previous experiences or cognitive frameworks. It also suggests that to get a complete picture of how variation is created and used to initiate cultural evolution, social and individual learning are best investigated together rather than as separate mechanisms.

5.2.2 Selective imitation

The findings from Chapter 3 and 4 indicate that children generated novel actions without the help of a model or specific prompts to tell them what action to perform. This eliminates the possibility that children's generation of novel actions as shown in other studies are solely due to imitation (e.g., Harris & Kavanaugh, 1993; Rakoczy *et al.*, 2004) or specific prompts to tell them what to do (e.g., Harris & Kavanaugh, 1993; Rakoczy *et al.*, 2004; Rakoczy & Tomasello, 2006). It suggests that children are indeed able to generate novel actions by themselves, and have the cognitive abilities to represent other objects even when these objects are not physically available, either through iconic gestures or through object substitution.

The data from Chapter 4 further suggest that children do not blindly copy any actions modelled by an experimenter. If children were to over-imitate during the object substitution task, they would have been expected to imitate the mistake actions during the Trying Condition. However, children were shown to correct the experimenter by showing the real action performed with that object. Similar findings were reported by Rakoczy *et al.* (2004) when using auto symbolic pretend actions. This indicates that children take into account the intentions of the experimenter and selectively imitate the actions that the experimenter intended to perform, while ignoring the unintentional actions.

The observation that children do not just rely on imitation or other social interactions in order to learn new things, but also explore new things on their own, is important. It can have significant implications for how parents perceive their role in their children's learning. As stated before in this chapter, the importance of social learning in the acquisition of new knowledge is evident. However, it is important to paint the whole picture and also emphasise individual learning, as this provides a more realistic view of how important the parents' direct influence is in a child's learning. Children also learn new things without their parents always being there to guide them. Rather than just focussing on modelling behaviour, our findings suggest that it can also be beneficial for children if parents give them their own space to explore for themselves.

5.2.3 Communication

Previous research has indicated that the most common ways of communicating for children is through speech and pointing (Özçalişkan & Goldin-Meadow, 2011). Gestures are mainly used to clarify aspects that are harder to verbalize (Campana, Silverman, Tanenhaus, & Benetto, 2004). Our study showed that, when talking and pointing are altogether impossible to use as means of communication, children do indeed switch to using iconic gestures in order to communicate. Although these findings display children's ability to switch to a different communication means, one must be cautious to interpret this as reflecting children's natural behaviour. In our experiment, an experimenter modelled beforehand how iconic gestures could be used in order to request the desired object. This might have given them the insight that using iconic gestures was a good alternative. However, we cannot say for sure whether children would have had this insight if the experimenter had not modelled the behaviour. This again reinforces the idea that social learning can provide an important framework for children when generating new behaviour. Future research could investigate whether children naturally switch to generating iconic gestures when speech and pointing are ineffective. In accordance with the study described in Chapter 3, speech and pointing should be ineffective responses since children are expected to use these means of communication before switching to gestures.

Poggi (2008) argued that in order to generate iconic gestures we select the features to imitate based on their distinctiveness and their ease to be represented by hands. The same is possibly the case for object substitution actions, although in this case it is also important to take the goal of the action into account. For iconic gestures, the main goal is thought to be to communicate to other people. Therefore it is most efficient to take the most distinctive features of an object to represent in the gesture. However, the goal of an object substitution action is not necessarily to communicate to others. When a child plays on his/her own and is not interested in whether other people understand what the substituted object is, it does not seem to matter how distinctive the action is, as long as the child knows and remembers what the object is supposed to be. However, when playing with others, it does seem important for the other person to understand the object substitution actions. Therefore, it is theorized that the child would make more distinctive object substitution actions when playing with someone else, compared to solitary pretend play. It would be interesting to investigate this further by comparing the object substitution actions of children during joint and solitary pretend play.

5.2.4 Theoretical model for generating novel actions

A new theoretical model to explain how children generate novel actions is proposed, which is displayed in Figure 1. The model was inspired by Piaget’s theory of cognitive development and the experiential learning theory, as it is based on the idea that children use previous knowledge and build upon this knowledge to guide their generation of novel actions. It also takes into account claims made by Vygotsky's dialectical theory and pedagogy theory, that social learning is an important initiator of learning new knowledge.

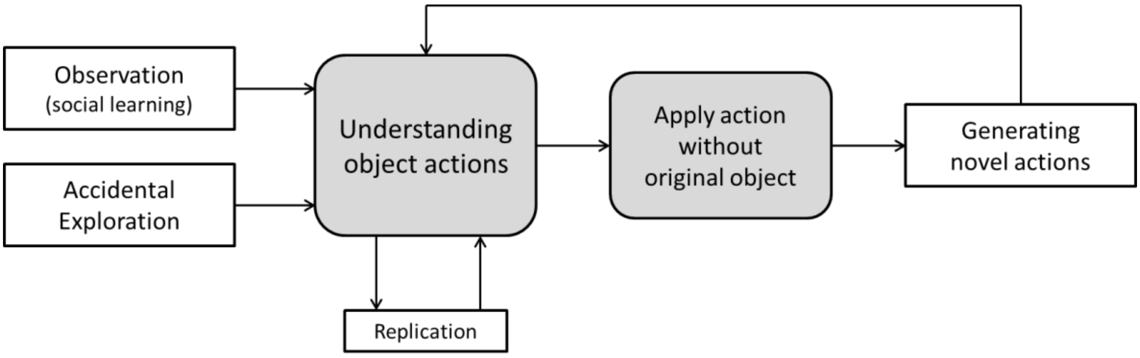

Figure 1: Proposed theoretical model displaying how children generate novel actions.

According to the model, children initially learn what actions on objects are possible through observation (social learning) and/or accidental exploration. Accidental exploration relates to any action a child performs on an object without the intention to explore. For example, when a child accidentally drops a ball on the floor and it bounces back, the child has learned something about what the ball can do without necessarily having intended to explore this option. Through accidental exploration and social learning children build a repertoire of what actions can be performed with each object. Replication of actions within their repertoire strengthens their understanding of these object actions, but does not add any new information.

Children's generation of novel actions through child-directed learning is thought to be based on the current knowledge they possess about object actions. That is, the actions within their repertoire are applied to new situations without the original object. It is this final stage which is applicable to the studies in this thesis as well. When given a novel object (Chapter 2), children are theorized to use their previous knowledge of other objects to guide their exploration of the novel object. This suggests that children’s exploration is more structured than solely through trial-and-error based learning, in which children would randomly act on the object without any expectation of what might happen. Instead it is theorized that children use similarities between a familiar and the novel object, for example in shape or texture, to guide their exploration. By using this strategy, the number of possible actions is decreased and, because it is based on what actions are possible with similar objects, it increases the likelihood that the action is feasible. As an example, the spatula used as a novel object in Chapter 2 showed similarities in texture (hard), and shape (a stick with a broad part on top) with a hammer. Children might have recognized these similarities and in response used more hammer-like actions (e.g., hitting parts of the Unusual Box).

On the other hand, children were not limited in their exploration of novel objects when it resembled a familiar object. For example, the egg cup was recognized as such by a number of children. However, instead of limiting themselves to using it only as an egg cup (e.g., asking for an egg to put in or placing it on the table), children also explored the other features it contained, most noticeably the spiral shape which made it possible to pull the egg cup apart or squeeze it together. This shows that they still explored the further possible actions of that object, possibly by linking it to other objects with similar features (e.g., other objects with a spiral shape).

The idea that children’s generation of novel actions is driven by their knowledge of actions with other objects is thought to be a structured and efficient way of generating novel actions. It filters out the number of initial possibilities by focusing on the most likely actions associated with the novel object. If in return the affordances of the familiar object do not match with the affordances of the novel object (e.g., it was not possible to hit things with the spatula after all), one can adjust the actions performed with the novel object and try other actions instead. Future research is required to give a more definitive answer to what strategies children use to explore novel objects. One possible experiment to investigate how much children's actions are guided by the physical similarities between the novel object and familiar objects could involve presenting children with a novel object that is physically very similar to a familiar object and other novel objects that are of decreasing similarity. If children rely on the physical similarities between the novel object and familiar objects, it is expected that the child would perform more actions alike actions performed with the familiar object when the novel object is physically very similar to the familiar object.

When generating iconic gestures (Chapter 3), children are thought to use their knowledge of what actions are normally performed with an object and perform the most typical action in the absence of the object (Poggi, 2008). Children still seem quite flexible in generating the iconic gestures, because they show body part gestures as well as representational gestures. Body part gestures require children to use a part of their hand as if it was the object (e.g., using a finger as if it is a toothbrush, by moving the extended finger over the teeth). Therefore the action they perform as an iconic gesture is different than the action they would normally perform when the object was present. The cognitive processes used when generating body part gestures are thought to resemble the processes when generating object substitution actions. During object substitution actions one object is used as if it was another object. Similarly, when generating a body part gesture children substitute their own hand for another object.

When generating object substitution actions (Chapter 4), we need to take into account children's understanding of two objects. First, children may (or may not) have knowledge or beliefs about what actions are possible with the object in hand. Second, children need to have an understanding of the possible actions with the substituted object in order to know what action to perform if they wanted to pretend that the object in hand was like the substituted object. Crucially, children would then need to suppress the actions normally performed with the object in hand and temporarily act upon the object as if it were the substituted object.

5.3 Individual differences

Our findings indicate that children as young as 2 years are able to generate novel actions. However, some children were found to be better at generating these actions than other children. These individual differences suggest that some children may be better skilled at generating novel ideas than others. This has important implications for the implementation of learning strategies within the education system. With the current emphasis on child-directed learning (The Department for Education, 2012) our results suggest that some children would benefit more from an individual learning strategy, in which they are given objects or learning content to explore on their own. On the other hand, children who do not seem to explore as much on their own might benefit more from a social learning strategy, in which a teacher guides the learning experience of the child by showing him/her new behaviours or emphasising certain aspects of the learning content.

The results from the studies described in this thesis cannot explain how these individual differences come about. The positive relationship between age and children's ability to generate multiple actions for novel objects (Chapter 2) suggests that children's ability to generate novel actions might improve with increasing age. Although this suggests that the ability to generate novel actions is a flexible trait, longitudinal studies are required to provide a clearer picture of how age affects the ability to generate novel actions within the same person.

Cognitive skills that were expected to influence children's ability to generate novel actions were divergent thinking and inhibitory control. Divergent thinking was positively correlated to the number of different actions children generated with novel objects. This indicates that, when no restrictions are given in what an object could be or what actions can be performed with it, children with higher divergent thinking scores generate more novel actions. However, divergent thinking scores had no effect on children's ability to substitute one object for another. In Chapter 4 this was argued to be because the pictures presented might have guided them to generate a specific action, therefore divergent thinking skills were not required. This suggests that divergent thinking might still be useful for generating object substitution actions when a child can use object substitution without restrictions. Although children's divergent thinking skills were initially not related to the number of object substitution actions performed during free play, exploratory analyses revealed that for children who performed at least one object substitution action, originality scores and the number of object substitution actions performed were positively correlated. It was argued that children might be guided in their play by functionally specific objects that are available, but that divergent thinking skills are relevant when no structure is given. This suggests that when parents or teachers want to encourage exploration and individual learning, this may work best in a free setting rather than in a structured game. Future research is needed however to investigate this relationship further.

Inhibitory control was hypothesized to be specifically important for children's ability to generate object substitution actions. During object substitution, children needed to temporarily inhibit the original action performed with that object in order to generate the object substitution object. However, children's inhibitory control and their ability to generate objects substitution actions, both in an experimental and naturalistic setting, were unrelated. This contradicts earlier findings which do indicate a relationship between inhibitory control and pretend play behaviour (e.g., Kelly, Dissanayake, Hammond, & Ihsen, 2011). In Chapter 3, the observation was already made that half of the children failed the practice trials. This means that even directly after being given the instructions of what word to say after which picture, children failed to answer correctly. This could indicate that the children assessed had generally low inhibitory control, resulting in a floor effect for half of the sample. Another alternative is that children had difficulty understanding the task. Gerstadt, Hong, and Diamond (1994) also observed that a large number of children failed to pass the practice trials. If 3-year-olds have difficulty understanding the task it might not be completely reflective of their inhibitory control skills. Although this measure was chosen intentionally because it required a child to inhibit one response and instead give an alternative response, similar to what is required when generating object substitution actions, it is worthwhile assessing inhibitory control skills with alternative measures to give a more decisive indication of the relationship between inhibitory control and the ability to generate novel actions.

It would be interesting to investigate other executive function skills as well. Working memory relates to our capacity to maintain and manipulate information (Baddeley, 1992). In adults, increased working memory has been linked to increased divergent thinking (e.g., De Dreu, Nijstad, Baas, Wolsink, & Roskes, 2012; Roskos-Ewoldsen, Black, & McCown, 2008), which was related to children’s ability to generate novel actions in this thesis. It is theorized that as one can maintain and manipulate more pieces of information, one has a greater capacity to generate combinations of actions as well as actions of greater complexity. Future research could investigate whether this relationship can already be found in children. Another executive function skill that would be interesting to explore is cognitive flexibility. Cognitive flexibility is defined as the ability to alter a behavioural response mode in the face of changing contingencies (Monchi, Petrides, Petre, Worsley, & Dagher, 2001); i.e., switching one’s behaviour when task demands change. It is commonly assessed using the Wisconsin Card Sorting task (e.g., Kaland, Smith, & Mortensen, 2008; Memari *et al.*, 2013; Ni, Huang, & Guo, 2011) and to a lesser extend the Trail making task (e.g., Kortte, Horner, & Windham, 2002; Longo, Kerr, & Smith, 2013). Cognitive flexibility is thought to be important for generating novel actions as well, especially for actions like object substitution. It requires children to switch from the original use of an object to the substituted action. In adults, cognitive flexibility has been linked to divergent thinking as well (e.g., Zabelina & Robinson, 2010). Future research could look specifically into the relationship between children’s cognitive flexibility and generating novel actions.

In addition to intrinsic factors that could have an effect on children’s ability to generate novel actions, it would be interesting to investigate extrinsic factors as well. One such factor could be parenting styles. Parenting styles relate to the way in which parents guide their children’s behaviour (e.g., through warmth, involvement, maturity demands, and supervision; Glasgow, Dornbush, Troyer, Steinberg, & Ritter, 1997). A permissive parenting style is associated with child-directed learning in which the child is allowed independence to explore (Baumrind, 1971). On the other hand, parents with an authoritarian parenting style dictate what their children should and should not do (Baumrind, 1971). Previous research suggests that children of parents with an authoritarian parenting style are less creative than children of parents with a permissive parenting style (e.g., Fearon, Copeland, & Saxon, 2013; Miller, Lambert, & Speirs Neumeister, 2012). It seems likely that children who are allowed to explore would be better able to generate novel actions than children who are mainly being told what to do. If parenting styles do affect children's ability to generate novel actions this could give opportunities to try and improve this ability by educating parents about the impact their parenting style has on the cognitive abilities of their child, or giving them training to change their parenting style.

5.3.1 Application of findings to Artificial Intelligence and robotics research

In the general discussion of Chapter 2, the application of our findings to artificial intelligence and robotics research was briefly discussed. The Unusual Box test was initially developed with the purpose to assess children's ability to generate novel actions. However, the same test could also be used in artificial intelligence and robotics research, to develop computational models that represent how children generate new actions, and investigate a wide array of factors that could affect individual learning. The test provides an easy tool to assess individual learning, and requires limited cognitive and linguistic demands.

In the development of computational models that represent how children generate new actions, two recommendations are made based on the findings in this thesis. First, computational models should take into account the finding that some children rely more on individual learning than others. As we found differences in the number of actions produced between children, a computational model developed to model the generation of new actions should produce similar outcomes. This means that the predicted behaviour should show a spread in the number of actions generated. Second, computational models should take into account how likely it is that an individual action is performed. In this thesis we found that some actions were performed more often than other actions. In Chapter 2, some actions were generated by more than 50% of the children while other actions were only performed by a single child. Similarly, in Chapter 3 it was found that when representing some of the objects all children performed one specific type of gesture, while for other objects children used a variety of gesture types. This suggests that some actions are more likely to occur than other actions. Computational models should make use of this information, for example by feeding the action frequencies found in our study directly into a computer programme that guides a robot's behaviour. Based on our findings, we cannot say conclusively why these differences occur. The theoretical model described in paragraph 5.2.4 suggests that children are guided in the generation of novel actions by their previous knowledge of other objects. If this is correct, an unequal distribution of action types is expected based on the resemblance of the object at hand in comparison to the experience with previous objects. We suggest using the theoretical model described to develop new computational models and compare the outcome from computer simulations or robot behaviour to validate or invalidate the theoretical model.

5.4 Conclusions

The main aim of this thesis was to provide a general investigation of children's ability to generate novel actions. Three different settings were used to offer a varied investigation of this ability. The findings indicate that children as young as 2 years have the ability to generate multiple actions with novel objects. In addition, 3-year-olds displayed the ability to generate iconic gestures and object substitution actions. These findings are an important addition to the current knowledge about children's action production, by showing that children indeed generate these actions be themselves, and do not only rely on direct imitation of other's behaviour or specific prompts to tell them what to do. It also strengthens the idea that children from a young age are able to create new ideas, which is an important skill to have in order to be able to adapt to changing circumstances. Whether it is possible to increase children's ability to generate novel ideas; through education, parental influences, or specific training; remains an important question to be answered in future research.

5.5 References

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Appendix A

Object Locations and Actions

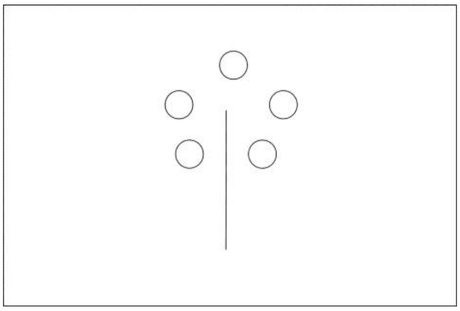
Object Locations
Round Hole
Rectangular Room
Stairs
Blocks
Rings
Strings
Edge of the Box
Side of the Box
Whole Box
No Box

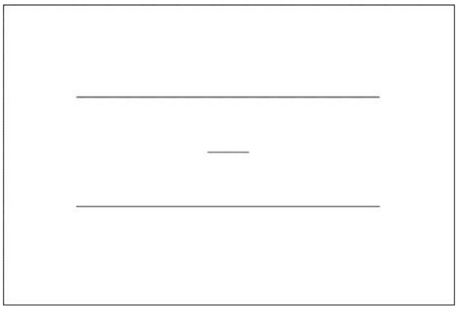
Actions	**Description**
Jump	Within a two-second period of time and for two or more times in a row, the object is placed on (part of) the box, then lifted in the air higher than needed for walking. During the placing of the object, it is kept hold of.
Walk	Within a two-second period of time and for two or more times in a row, the object is placed on (part of) the box. During the placing of the object, it is kept hold of.
Hit	The object hits the box.
Touch	The object touches the box.
Roll	The object is rolled over the surface of the box, either holding it or letting it go.
Turn	The object is turned around.
Drop	The object is held above the place where it will land, and then let go.
Guide through	While holding the object it is guided through (part of) the box without stopping.
Hold in place	The object is placed on (part of) the box. During the placing of

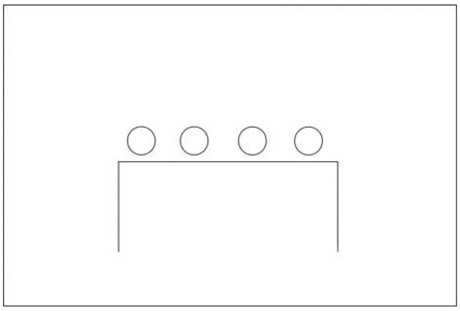
	the object it is kept hold of.
Place	The object is placed on part of the box and let go so that it stands on its own for a while.
Move over	While holding the object, it is guided on part of the box and then moved over its surface.
Pull	(Part of) the box/object is pulled toward the participant.
Push	(Part of) the box/object is pushed away from the participant.
Squeeze	The object is squeezed, using thumb and index finger.
Cover	Part of the box is covered by the object.
Throw against	The object is thrown against the box.
Hang	The object is attached to the box (e.g., by manipulating the object) and let go so that it hangs on the box.
Shake	The object is held in the hand(s) and moved quickly from one side to the other.

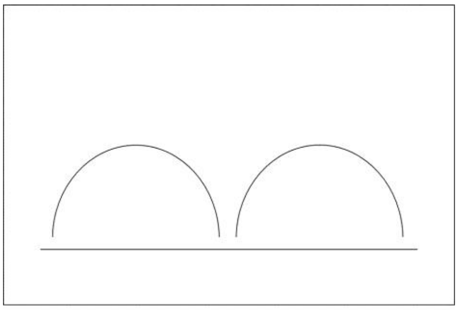
Appendix B

Items used for the Pattern Meanings subtest









Appendix C

Object Pairs

Model Trials

Easy Pairs		Difficult Pair	
Glasses	Microphone	Toothbrush	Lipstick
Xylophone	Tissue		

Extension Trials

Easy Pairs		Difficult Pairs	
Drum	Cup	Drum	Ball
Ball	Spoon	Cup	Spoon
Hammer	Harmonica	Hammer	Shaker
Shaker	Whistle	Harmonica	Whistle
Pen	Hairbrush	Pen	Paintbrush
Paintbrush	Hat	Hairbrush	Hat
Glove	Watering Can	Glove	Soap
Soap	Shovel	Watering Can	Shovel

Appendix D

Order of object pairs used in the Test Phase of the pretend experiments in Studies 1 and 2

Order 1

Phase	*Object Presented*	*Other Picture*
Model	Ball	Cup
	Piano	Camera
	Hat	Glove
	Toothbrush	Whistle
Extension	Hammer	Brush
	Shaker	Pen
	Soap	Glasses
	Phone	Drum

Order 2

Phase	*Object Presented*	*Other Picture*
Model	Hammer	Brush
	Shaker	Pen
	Soap	Glasses
	Phone	Drum
Extension	Ball	Cup
	Piano	Camera
	Hat	Glove
	Toothbrush	Whistle

Order 3

Phase	*Object Presented*	*Other Picture*
Model	Cup	Ball
	Camera	Piano
	Glove	Hat
	Whistle	Toothbrush
Extension	Brush	Hammer
	Pen	Shaker
	Glasses	Soap
	Drum	Phone

Order 4

Phase	*Object Presented*	*Other picture*
Model	Brush	Hammer
	Pen	Shaker
	Glasses	Soap
	Drum	Phone
Extension	Cup	Ball
	Camera	Piano
	Glove	Hat
	Whistle	Toothbrush

Appendix E

Pictures of objects used in the pretend experiments in Studies 1 and 2

Familiarization Phase:

Test Phase:

Appendix F

Actions performed on each object, and sounds effects made in the Pretend Condition (for both the Implicit and Explicit Group)

Object Presented	**Target Object**	**Action**[1]	**Sound Effects Pretending**
Ball	Cup	Holding the ball in a way you would normally hold a cup and bringing the ball to the mouth, pretending to drink from it.	Slurping sound – as if drinking from a cup
Cup	Ball	Taking the cup in two hands and holding it a bit above the table, in a way you would normally hold a ball before bouncing it. Then bouncing the cup on the table while making sound effects.	“Boing Boing” – as if bouncing a ball
Piano	Camera	Holding the piano with two hands on each side, in a way you would normally hold a camera. Bringing the piano to the eye, as if looking through the viewfinder. Then pressing with one finger on top of the piano, as if taking a picture.	“Click click”
Camera	Piano	Placing the camera flat on the table, then moving hands from left to right over the camera, while moving fingers as if playing piano.	Singing melody as if playing a tune
Hat	Glove	Holding the hat in one hand, while holding the other hand above the table with fingers spread. Sliding the hat over her hand from fingers to wrist, then letting go of the hat and looking at the hat on her hand.	“Ohhhh” – as if admiring how pretty the glove is

Glove	Hat	Picking up the glove with two hands, in a way you would normally hold a hat. Placing the glove on top of her head, and holding hands to the side as if showing off the hat	"Ohhhh" – as if admiring how pretty the hat is
Toothbrush	Whistle	Picking up the toothbrush with two hands, in a way you would normally hold a whistle (recorder). Bringing the toothbrush to the mouth and moving fingers as if playing.	Singing melody as if playing a tune
Whistle	Toothbrush	Bringing the whistle to a short distance in front of the mouth in a way you would normally hold a toothbrush. Opening mouth so that teeth are visible, then moving hand from left to right in front of teeth.	"Shhh shhh shhh" – like the sound of the toothbrush on the teeth
Hammer	Brush	Holding the hammer in one hand, in a way you would normally hold a hair brush. Bringing the hammer to the hair and moving hand up and down over the hair, as if brushing it.	"Shh shh" – as the sound a hair brush makes when going through hair
Brush	Hammer	Holding the brush with the bristles to the side, in a way you would normally hold a hammer. Banging the brush three times on the table.	No sound effects, other than the banging sound of the brush
Shaker	Pen	Holding the shaker in a way you would normally hold a pen. Making movements with the end of the shaker on the table as if she is writing.	"Ohhhh" – as if admiring what she has written
Pen	Shaker	Holding the pen with writing end firmly in one hand in a way you would normally hold a shaker.	"Cha-cha" – as the sound a shaker makes

		Shaking pen quickly on one side of the body, then moving hand to other side and making another shaking movement.	when shaking it
Soap	Glasses	Picking up the soap with two hands, one hand on each side. Bringing the soap to face on the top of the nose, covering the eyes. Moves head from left to right and back as if looking through glasses.	"Ohhhh" – as if admiring the view she sees through the glasses
Glasses	Soap	Holding the glasses (closed) in one hand. Moving other hand over the glasses, then placing it in the other hand and moving the spare hand over the glasses, as if washing hands with soap.	"Lalala" – as if enjoying washing hands
Phone	Drum	Placing the phone flat on the table, then hitting phone in turns with both hand on the phone.	No sound effects, other than banging sound of the hands on the phone
Drum	Phone	Taking the drum in one hand by the rim. With the other hand, using the index finger to hit the drum as if pressing buttons on a phone. Then bringing the drum to one ear.	"Hello?" when bringing the drum to the ear

[1] *Every action was repeated twice, with some pauses in which the experimenter looked at the object (Trying Condition) or at the child (Pretend Condition).*

Appendix G

Description of levels of behaviour and examples of children's behaviour at each level. Based on the Exploratory Behaviour Scale by Van Schijndel, Franse, and Raijmakers (2012).

Level 1: Passive contact

A child touches, holds, or transports an object, without manipulating the object in an active or attentive manner.

- A girl holds her hand on the xylophone, while talking to her mother.
- A boy transports the dog stuffed animal from the tray to right in front of him.
- A girl touches the shape sorter with her finger, without moving it or actively exploring the object.

Level 2: Active manipulation

A child manipulates an object in an active and attentive manner. This implies that the child pays attention to his or her action(s) and the outcomes of the action(s).

- A boy hits the xylophone with the hammer.
- A girl places blocks on top of each other, building a tower.
- A boy pulls a red bendy stick on both sides so that it extends, then pushes on both sides so that it contracts.

Level 3a: Clear pretending (Autosymbolic)

A child uses an object in a way that is normally used, but he or she attributes features to the object which are not present, or pretends inanimate objects are animate. The pretend act can be accompanied by sound effects or words explaining the pretend setting.

- A girl uses a sponge to wash the dog stuffed animal (no water present).
- A boy pours imaginary tea from teapot into cup (no tea present).
- A girl brings two puppets with their faces close together, and makes kissing sounds.

Level 3b: Clear pretending (Object Substitution)

A child uses an object as if it is something else. The pretend act can be accompanied by sound effects or words explaining the pretend setting.

- A boy takes a red bendy stick and holds it in the cup while stirring it around in the cup like a spoon.

- A girl holds the blue, snakelike, sponge in one hand and pulls on the cord attached to the sponge with her other hand, while saying, “It is a catapult!”
- A girl takes a puppet and places it near the blocks that are stacked like a house, while saying, “This is the girl’s house.”

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