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

Individual Differences and Age-related Changes in Divergent Thinking in Toddlers and Pre-schoolers

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 behaviors, 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 modeled 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 behavior (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.

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 behaviorally (showing examples in movement), and the child can respond both verbally and behaviorally.

Method

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.

Materials

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 colors. 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 colors, 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 here >

Instances

Three out of four items of the Instances subtest 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. A voice recorder (Olympus) was used to record the children’s answers.

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 A). 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.

TCAM

The TCAM consists of four subtests. For the “What might it be” subtest, five white polystyrene cups were used. For the “How many ways” subtest, two lines were created on the floor (approximately 1.5 meters apart) using duct-tape. The “What other ways” subtest required the same polystyrene cups as used in the first subtest and a small garbage bin. No additional materials were used for the subtest “Can you move like?” 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.

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.

Procedure

The child was taken out of the class into a separate room. After a short warm-up in which the child was asked what his or her favorite color and animal was, he or she was presented with the Unusual Box test, the Instances and Pattern Meanings subtest, or the TCAM.

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.

Instances

The child was asked to name as many things that could encompass a statement as they could think of (e.g., "Name all round things you can 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.

Pattern Meanings

The child was presented with a drawing (see Appendix A) 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.

TCAM

All four subtests of the TCAM 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. 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?" 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 analyzed. For the last subtest, "What other ways?" 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. There was no time limit on children's responses in any subtest.

Coding

Unusual Box test

Each trial started the moment that the child took the novel object from the experimenter, and lasted for 90 seconds. 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). Actions were recorded on two features: what action was performed (e.g., jump, hit, place; for full list see Appendix B) and what part of the box was used during the action (e.g., ledges, round hole, see Appendix B). 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 for 20% of the videos was good (k = 0.81).

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

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.

A uniqueness score (originality) was 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 fluency and originality scores for each child were coded in the same way as in the Instances subtest.

TCAM

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.

Results

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 here >

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 here >

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.

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.

Method

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.

Materials

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

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.

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.

Coding

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

Results

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. Children extended their use of the novel objects on the second assessment, compared to the first assessment, with on average 9.0 novel actions (*SD* = 3.2, *range* = 4-15). The fluency scores of the second assessment were positively correlated to the number of novel actions performed on the second assessment (Pearson's $r = .782$, $p < .001$). This suggests that the higher the fluency score the more novel actions a child performed on the second assessment. Furthermore, older 2-year-olds were more likely to produce novel actions on the second assessment than younger 2-year-olds (Pearson's $r = .592$, $p = .016$).

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.

Age differences on the use of the Unusual Box

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* $r = .314$, $p = .049$).

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 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.

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.

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 modeled 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 modeling 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.

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 behavior. At a young age, children may derive more benefit from observational learning than from individual learning, because the amount of observed behavior that is novel to the child is more abundant. When children then produce the observed behavior themselves, we call it imitative rather than creative behavior. However, for the child, performing this behavior 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 behavior 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.

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.

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.

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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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

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

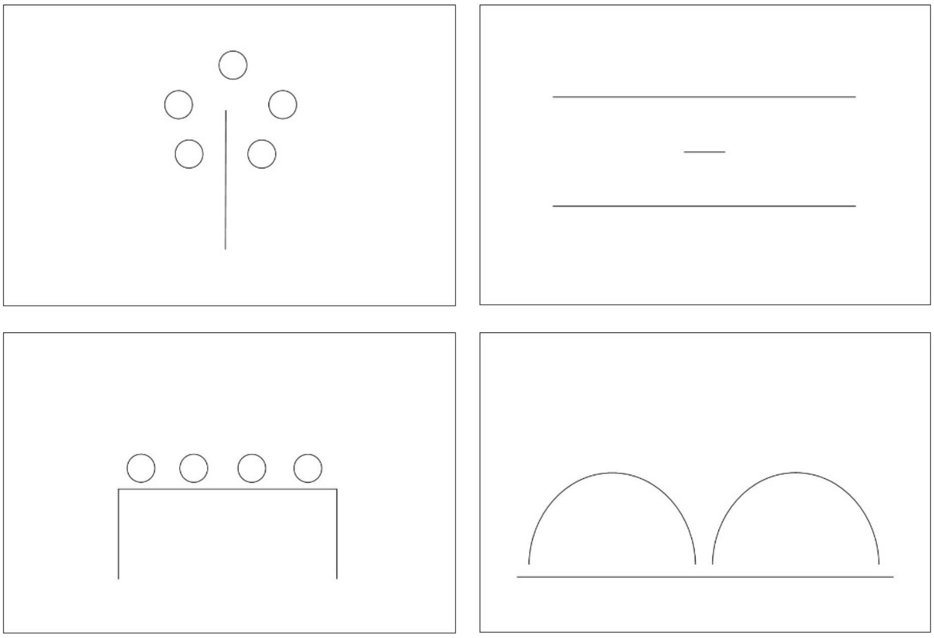
Figure Captions

Figure 1. The Unusual Box and the novel objects.

Figure 1

Appendix A

Items used for the Pattern Meanings subtest



Appendix B

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.