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Two-Year-Olds can Socially Learn to Think Divergently

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Abstract

This study aimed to discover whether 2-year-olds can socially learn to think divergently. Two-year-olds (*N*=22) who saw an experimenter model a high level of divergent thinking on the Unusual Box Test (modeling 25 different actions, once each) went on to demonstrate a higher level of divergent thinking themselves than (*N*=22) children who saw a low level of modeling (5 different actions, each), where divergent thinking was measured by the number of different actions children produced that had not been modeled by the experimenter. Additionally, all children in both High and Low Divergence conditions had higher divergent thinking than imitation scores, where imitation involved copying the experimenter's previous actions. This is the first experiment to show that 2-year-olds' divergent thinking can be increased, and that 2-year-olds do so by socially learning to think more divergently.

Keywords: Divergent Thinking; Imitation; Individual Learning; Social Learning; Creativity; Exploration

Two-Year-Olds can Socially Learn to Think Divergently

Adaptation and innovation are defining features of humans (Kirton, 1989; Mesoudi, Whiten, & Laland, 2004). Major institutions such as the World Bank and the British Government take innovation seriously, crediting it with leading to new business ideas, changes in policy, and economic prosperity (Department for Business, Innovation, & Skills, 2009; King, 2014). It may be for these reasons that creativity is now prevalent in education, featured in curricula around the world, including every EU member state (Cachia, Ferrari, Ala-Mutka, & Punie, 2010; UNESCO, 2006). Divergent thinking is a creative thought process which involves the generation of several ideas within one problem space (Torrance, 1974). For instance, one could think of many things to do with a brick (Guilford, 1967), e.g., use it as a paper weight, as a step, for bicep curls, and so on. Children's divergent thinking at 7 years predicts future creative achievements and careers up to 50 years later (Cramond, Matthews-Morgan, Bandalos, & Zuo, 2005; Plucker, 1999; Runco, Millar, Acar, & Cramond, 2010; Torrance, 1981a), suggesting early interventions to increase divergent thinking could be very useful. However, while meta-analyses demonstrate that interventions to increase creativity and divergent thinking in school-aged children and adults are effective (Scott, Leritz, & Mumford, 2004a, 2004b), there are no studies which show we can increase divergent thinking in preschool-aged children, when neuro-development is still highly plastic (Fox, Calkins, & Bell, 1994; Joseph, 1999). The goal of the current study is to determine whether social learning can be used to increase divergent thinking in 2-year-olds.

Divergent thinking has been measurable in children from 3 years for several decades. The Wallach and Kogan Tests of Creativity (Wallach & Kogan, 1965) ask questions such as "Name all round things you can think of" (e.g., ball, sun, coin, orange, etc.). In 1981, Torrance developed the Thinking Creatively in Action and Movement task (TCAM) (Torrance, 1981b) to create a less verbal measure of divergent thinking suitable for 3-year-olds. This task involved, for instance, moving between two lines in as many different ways as possible (e.g., walk, hop, crab-walk, skip, etc.).

More recently, Bijvoet-van den Berg and Hoicka (2014) developed a non-verbal, non-imitative divergent thinking task usable from 1 year (Hoicka et al., 2016). The Unusual Box Test (UBT) is a colorful wooden box with many features (see Figure 1). Children play freely with it alongside five novel objects. Divergent thinking is calculated as the number of different action-box area combinations children generate. For instance, they might hit the edge of the box, and then guide an object through the hole. The UBT shows good test-retest reliability in 1- and 2-year-olds (Bijvoet-van den Berg & Hoicka, 2014; Hoicka et al., 2016). It shows convergent validity in 3- and 4-year-olds with two other widely used standard measures of divergent thinking in preschoolers – the TCAM (Torrance, 1981b) and the Wallach and Kogan Tests of Creativity (Wallach & Kogan, 1965). Additionally, one-year-olds' scores on the UBT correlate well with parents' scores (Hoicka et al., 2016) on the widely-used divergent thinking measure Thinking Creatively with Pictures (Torrance, 1966). The UBT allows us for the first time to determine whether we can increase divergent thinking in children under 3 years.

Figure 1. Novel box and five novel items.

There have been several effective divergent thinking interventions in younger children (Cartledge & Krauser, 1963; Cliatt, Shaw, & Sherwood, 1980; Dziedziewicz, Oledzka, & Karwowski, 2013; Khatena, 1971; Lee, Bain, & McCallum, 2007; Liberman, Polack, Hameiri, & Blumenfeld, 2012; Subbotsky, Hysted, & Jones, 2010). These interventions involved various methods, such as giving children extensive practice in thinking divergently, e.g., asking them many divergent thinking questions (Cliatt et al., 1980; Dziedziewicz et al., 2013; Khatena, 1971); giving explicit instructions on how to think divergently (Cartledge & Krauser, 1963; Lee et al., 2007); priming spatial distance (Liberman et al., 2012); and watching magical videos, such as Harry Potter (Subbotsky et al., 2010). However, only two studies tested children as young as 4 years (Dziedziewicz et al., 2013; Subbotsky et al., 2010), and none have tested younger children, likely because no DT measures existed for younger children until recently. While effective, these strategies would be unsuitable for 2-year-olds because they involved verbal skills (Cartledge & Krauser, 1963; Cliatt et al., 1980; Lee et al., 2007; Subbotsky et al., 2010), creating pictures (Dziedziewicz et al., 2013; Khatena, 1971), or advanced conceptual knowledge (Liberman et al., 2012).

One way in which we might increase toddlers' divergent thinking is through social learning. On the surface, social learning appears at odds with divergent thinking. For instance, a new theoretical model considers the circumstances under which children *either* imitate or innovate (Legare & Nielsen, 2015). Adults who focus on advancement and accomplishment produce less creative work after imitating other good examples of work (Rook & Knippenberg, 2011). Five-year-olds explore objects less after a social demonstration (Wood, Kendal, & Flynn, 2013), and both 3 to 5-year-olds, and 4- to 9-year-olds prefer to imitate rather than innovate, leaving innovation as a last resort when the model is not efficacious (Carr, Kendal, & Flynn, 2015; Flynn, Turner, & Giraldeau, 2016). When an experimenter models an action on a novel object while giving communicative cues, 4- and 5-year-olds imitate the modeled action and explore less compared to when no demonstration is made (Bonawitz et al., 2011). This strategy may be advantageous for learning. In a computational simulation, the most effective strategy relied mostly on social learning (imitation) rather than a more equal combination of social and individual learning (generating one's own ideas) (Rendell et al., 2010). This may be because others do the hard work of determining what works best, and imitators reap the benefits with little cost to themselves.

However, research suggests social learning sometimes increases divergent thinking. In one study, adults came up with different uses for familiar objects. Adults in groups copied each other, leading to more ideas on a subsequent individual task, compared to adults who always worked alone (Andre, Schumer, & Whitaker, 1979). Adults with the option to imitate others in a search task produce more creative search solutions (Wisdom & Goldstone, 2011). Perhaps, by working in groups, adults witness a high collective level of divergent thinking, which can then encourage them to increase their own divergent thinking.

From a developmental perspective, adolescents who watched a creative model showed higher level of divergent thinking than adolescents who watched no model (Yi, Plucker, & Guo, 2015). Ten-year-olds who watched a model showing high divergent thinking fluency (number of different ideas) or originality (number of unique ideas) showed higher divergent thinking fluency and originality than children who saw poor quality models (Belcher, 1975; Zimmerman & Dialessi, 1973). Additionally, when a peer model has been proficient in a task, and then innovates, this encourages innovation in other children (Wood, Kendal, & Flynn, 2015).

In terms of toddlers, 2- and 3-year-olds produce novel jokes after imitating jokes of a similar style (Hoicka & Akhtar, 2011), and more novel pretend acts after watching someone pretend (Nielsen & Christie, 2008). Furthermore, parents' and toddlers' divergent thinking correlate well, and one possible mechanism for this is that toddlers socially learn their divergent thinking style from their parents (Hoicka et al., 2016).

The differences between the above sets of studies may have to do with what is being socially learned. If a low level of divergent thinking is modeled, children may demonstrate a low level of divergent thinking as well, assuming the goal is to imitate, rather than explore (Bonawitz et al., 2011; Carr et al., 2015; Wood et al., 2013). In contrast, if a high level of divergent thinking is modeled, children may demonstrate a high level of divergent thinking as well, assuming the goal is to explore (Hoicka & Akhtar, 2011; Hoicka et al., 2016; Nielsen & Christie, 2008).

The current study sought to determine whether modeling a high level of divergent thinking would increase divergent thinking, and modeling a low level of divergent thinking would decrease it. In the baseline condition, children were tested on the UBT as normal, without any modeling by the experimenter. Therefore all actions that children performed contributed to their divergent thinking score. In the High Divergence/High Activity condition, children were shown five actions per trial (25 across the study), using a different object for each trial, before playing with the box and each object. If a child produced any action previously modeled by the experimenter, this was considered imitation, even if the child used a different object. Therefore producing the same action with a different object was considered imitation, not divergent thinking. If the child produced a novel action, this contributed to the divergent thinking score. In the Low Divergence conditions, children were shown one action per trial (five across the study), using a different object for each trial, before playing with the box and each object. In the Low

Divergence/Low Activity condition, each action was shown once. In the Low Divergence/High Activity condition, each action was shown five times in a row. It is important to note that the total possible divergent thinking score is actually lowest in the High Divergence/High Activity condition, since 25 possible actions would be counted as imitated. Please see Table 1 for a summary of the number of actions that could be classified as imitation or innovation by condition. Yet counter-intuitively, we predict that children will have the highest divergent thinking scores in this condition because children might socially learn to think divergently.

Table 1. Total possible scores for imitation and divergent thinking by condition. Since one action was always modeled before the very first trial in the Low Divergence conditions, that action could never be coded as divergent thinking. However, if children produced actions that would be modeled on later trials before they were actually modeled, those actions could count as divergent thinking, allowing a score of up to 179 out of 180. Similarly, since five actions were always modeled before the very first trial in the High Divergence condition, those actions could never be coded as divergent thinking. However, if children produced actions that would be modeled on later trials before they were actually modeled, those actions could count as divergent thinking, allowing a score of up to 175 out of 180. If children produced an action already modeled, even if they did so with a different object, it was counted as imitation, not divergent thinking.

Condition	Imitation	Divergent Thinking
Baseline	0	180
Low Divergence/Low Activity	5	179
Low Divergence/High Activity	5	179
High Divergence/High Activity	25	175

Two Low Divergence conditions were included for the following reasons. First, if the High Divergence condition increased divergent thinking over baseline, but the Low Divergence/Low Activity condition did not, this could be because the former condition showed five times as much activity as the latter. Children may then increase their overall activity level, indirectly leading to increased divergent thinking. If this is the case, we would also expect an increase in divergent thinking in the Low Divergence/High Activity condition. Second, if the High Divergence/High Activity condition increased divergent thinking over baseline, but the Low Divergence/High Activity condition did not, this could be because the repetition of actions in the latter condition made children more likely to infer the goal was to imitate the modeled actions, at the expense of divergent thinking. If this is the case, we would expect an increase in divergent thinking in the Low Divergence/Low Activity condition, where children would be less likely to infer the goal was to imitate since actions were also shown only once.

This data will also determine the relationship between imitation and divergent thinking in two different ways. First, following Bonawitz et al. (2011), Carr et al. (2015), and Wood et al. (2013), do toddlers imitate more than they think divergently? In the above studies, children were more likely to imitate than innovate on a goal-specific task (e.g., getting a prize from a box). We expected to find the same results in the Low Divergence conditions, which are more similar to previous studies. However, we expected the reverse in the High Divergence condition since children may perceive the goal to be to think divergently, or they may build on modeled actions to recombine and come up with more ideas (Legare & Nielsen, 2015). This is despite the fact that children in the Low Divergence conditions could imitate five actions and innovate from a selection of up to 179 actions, while children in the High Divergence condition could imitate 25 actions and innovate up to 175 actions.

Second, does a greater amount of imitation lead to lower divergent thinking scores, such that there is an overall trade-off between imitation and divergent thinking? When 4- to 9-year-olds are shown no model, most children will figure out how to solve a problem on an artificial fruit box (Carr et al., 2015). However, when shown a model, most children imitate more than they innovate. However, 2-year-olds have a lack of knowledge since they still have much to learn about the world. Therefore rather than imitation hindering divergent thinking, it may help toddlers as it could provide them with a larger knowledge base upon which to think divergently, in which case we would expect a positive correlation between both types of learning. Additionally, research on birds suggests that they use individual learning in order to adequately imitate bird songs (Galef, 2013). Therefore, it may also be beneficial to imitation to think divergently.

Method

Participants

Power analyses determined 76 participants were needed with α=0.05, β=0.80, and a large effect size (f=0.4) (Faul, Erdfelder, Lang, & Buchner, 2007). Eighty-five children participated. There were 22 children in the baseline condition: *M* = 30 months; 7 days, *SD* = 3;9, *Range* = 24;22 - 35;27, 13 boys, 9 girls. There were 22 children in the Low Divergence/Low Activity condition: *M* = 30;21, *SD* = 3;20, *Range* = 24;20 - 35;29, 11 boys, 11 girls. There were 19 children in the Low Divergence/High Activity condition: *M* = 29;25, *SD* = 2;14, *Range* = 25;0 – 34;23, 10 boys, 9 girls. Finally, there were 22 children in the High Divergence/High Activity condition: *M* = 31;6, *SD* = 3;4, *Range* = 26;0 – 35;15; 11 boys, 11 girls. Eighty-three children were Caucasian, and two were of mixed Asian/Caucasian ethnicity. Parents had a postgraduate degree (29), undergraduate degree (30), high school diploma (18), or did not report their education level (6). Additional children were not included due to equipment failure (2), or refusal to participate (2). All children lived in a city. All parents gave written consent, and the study was stopped if children did not want to participate (e.g., refusing to interact, crying). Participants were recruited through Bounty Pack mail outs, visits to a local maternity ward, social media, and a local museum. Data were collected from October 2013 until September 2015.

Materials

The UBT is a colorful wooden box (see Figure 1). It contains several features: blocks/ledges attached to one of the external walls, strings attached to a wire hung over one of the short sides of the box, rings attached to another external wall, a round hole cut into the final external wall, a small room, and stairs inside the box. The UBT also involves five objects novel to the participants: a metal spiral-shaped egg holder, a plastic unusually-shaped spatula, a rubber toy, a plastic hook, and a shaker (see Figure 1). Two Sony Handycam camcorders recorded the sessions.

Design

A between-participants design was used. In the baseline condition, the experimenter (E) did not model any actions before handing the object to the child (C). The baseline condition followed the same procedure as the original UBT (Bijvoet-van den Berg & Hoicka, 2014). In the Low Divergence/Low Activity condition, E modeled one action with each object once before handing it to C, for a total of five different actions across the study. In the Low Divergence/High Activity condition, E modeled one action with each object five times before handing it to C, for a total of five different actions across the study, each repeated five times. In the High Divergence condition, E modeled five different actions with each object before handing it to C, for a total of

25 different actions across the study. The dependent variables were divergent thinking (non-imitated actions), and imitated actions.

The decision to demonstrate one action per trial in the Low Divergence conditions was based on Bonawitz, et al.'s (2011) procedure where only one action was modeled in the experimental conditions. As two-year olds produce on average 19.3 different actions in the UBT (with a standard deviation of 5.9, and a range of 10-32) (Bijvoet-van den Berg & Hoicka, 2014), five actions were demonstrated per trial in the High Divergence condition. This resulted in a total of 25 different actions being shown to the children, a higher total than the average 2-year-old would invent themselves. In the Low Divergence conditions, children saw a subset of five of the 25 possible actions (one per object). There were five different subsets of five actions, counterbalanced across participants. Actions chosen in the conditions were those for which fewer than 50% of children in a previous sample spontaneously performed without input (Bijvoet-van den Berg & Hoicka, 2014). Indeed, most of these actions were performed by fewer than 20% of children in the previous study. If high frequency actions were used, children's novel action scores in the modeling conditions might be artificially low as popular responses would only be subtracted for these groups. However, actions were chosen that had been performed by at least one child in a previous sample to ensure it was possible children could produce the action. See Appendix A for the list of actions. Object order was counterbalanced within each condition.

Procedure

Testing took place in a university lab. Parents sat in the same room as C during testing, but away from the table. Parents were instructed not to show or tell C anything. In all conditions, the box was placed on a turntable to ensure all features of the box could be accessed by C. All features of the box were highlighted by E ("On this side there are blocks of different sizes") and

C was allowed to turn the box around using the turntable. Then E picked up one of the objects, ensured C was paying attention by saying, “Look!”, and either held up the object for C to see (baseline condition); modeled one action with the object once (Low Divergence/Low Activity condition); modeled one action with the object five times (Low Divergence/High Activity condition); or modeled five different actions with the object once each (High Divergence/High Activity condition). The object was then handed to C and E smiled, without saying anything, and a 90 second trial period commenced where C played freely with the object and box. After 90 seconds, E stopped C playing, praised them, removed the object and said they had a new toy for them to play with. This was repeated for all five objects. If C asked what the object was or how to use it, E used standardized responses, such as, “Just play a little while longer.”

Coding

Actions were coded from video based on the type of action performed (e.g., hit, place or squeeze, out of a total of 18 possible actions, based on Bijvoet-van den Berg & Hoicka, 2014) and where on the box the action was performed (e.g., rings, edge of box, out of a total of 10 possible locations; for full coding scheme, see Bijvoet-van den Berg & Hoicka, 2014). Children could theoretically produce up to 180 action-box area combinations at any point across the five 90-second trials. If C performed the same action in the same place, it was not coded again, even if a different object was used. It is important to note that all objects afforded all actions modeled. Sixteen videos (19%) were coded for agreement. We examined whether each action-box area combination was counted by both raters, neither rater, or one rater. The inter-rater agreement was good, *Cohen’s kappa* = 0.72.

We then divided the action-box area combinations into imitated and non-imitated actions. Actions were counted as imitated if E modeled the action-box area combination before C performed it, even if C used a different object. Actions were counted as non-imitated if C performed the action-box area combination before E performed it, or if E never performed it all. The total of non-imitated actions was then taken to be the divergent thinking score, as these were actions that children came up with themselves. It is important to note that in the Baseline condition, all actions by default contributed to the divergent thinking score since no actions were modeled. It is important to note that modeling conditions had a divergent thinking penalty, since children received no credit for modeled actions, potentially reducing their divergent thinking scores by five in the Low Divergence conditions, and by 25 in the High Divergence condition.

Results

No effects of, or interactions with age (in days) were significant, so age was not included in the final models. Divergent thinking scores within the Low Divergence/Low Activity condition were not normally distributed, so data were checked for whether outliers (more than 1.5 times the interquartile range from the median) caused skewness. One outlier caused skewness, so was removed (Judd, McClelland, & Culhane, 1995). See Table 2 for descriptive statistics.

The first question was whether modeling affected divergent thinking scores. An ANOVA with divergent thinking score as the DV, and with condition (Baseline; Low Divergence/Low Activity; Low Divergence/High Activity; High Divergence/High Activity) as a between-subjects factor, found a main effect of condition, $F(3, 80) = 4.93$, $p = .003$, $\eta_p^2 = 0.156$. Planned Tukey contrasts found children had significantly higher divergent thinking scores in the High Divergence/High Activity condition than in the Low Divergence/Low Activity condition, $p = .002$. There were no other significant differences between conditions.

Table 2. Mean number of actions, confidence intervals (in brackets), and ranges (in italics) for imitation and divergent thinking scores across conditions.

Condition	Imitation	Divergent Thinking
Baseline	NA	20.32
		(18.00-22.63)
		11-31
Low Divergence/ Low Activity	1.71	17.95
	(1.05-2.38)	(16.09-19.82)
	0-5	*10-24*
Low Divergence/ High Activity	3.05	21.00
	(2.46-3.64)	(18.34-23.66)
	1-5	*11-31*
High Divergence/ High Activity	4.73	23.59
	(3.82-5.64)	(21.61-25.58)
	1-8	*17-32*

The second question was whether children would be more likely to imitate than think divergently in the Low Divergence conditions, while showing the reverse pattern in the High Divergence/High Activity condition. However, all children had higher divergent thinking than imitation scores in all modeling conditions. Furthermore, all children demonstrated divergent thinking by displaying at least ten different actions across the study, however, five out of 62 children did not imitate at all (all five in the Low Divergence/Low Activity condition). As such, significantly more children in the Low Divergence/Low Activity condition demonstrated divergent thinking than imitation, Wilcoxon $Z = 2.24$, $p = .025$.

The final question was whether imitating more actions related to an increase or decrease in divergent thinking at an individual differences level. A forward stepwise regression model with divergent thinking scores as the DV, and the number of modeled (five or 25) and imitated actions as IVs, found the number of modeled actions significantly predicted divergent thinking scores, $\beta = 1.05$, $t(59) = 3.22$, $p = .002$. Once modeled actions were accounted for, the number of imitated actions did not predict divergent thinking scores, $\beta = 0.01$, $t(59) = 0.07$, $p = .941$. The number of modeled actions explained a small significant proportion of variance in divergent thinking scores, $R^2 = .15$, $F(1, 59) = 10.37$, $p = .002$. Furthermore, correlations between divergent thinking and imitation within each modeling condition were non-significant, all *Pearson's r* < .13, $p > .479$. Therefore there was no trade-off, or benefit, between imitation and divergent thinking scores at an individual differences level.

Discussion

Divergent Thinking

Modeling a high level of divergent thinking increased children's divergent thinking by around 31% over the Low Divergence/Low Activity condition (although there was no difference from baseline). This is despite the fact that this condition most limited the number of novel actions children could produce, as the 25 modeled actions could not count towards their divergent thinking scores if the experimenter modeled them first. This converges with past research finding a high level of creativity increases others' creativity in open-ended tasks (Andre et al., 1979; Belcher, 1975; Hoicka & Akhtar, 2011; Nielsen & Christie, 2008; Wisdom & Goldstone, 2011; Yi et al., 2015; Zimmerman & Dialessi, 1973).

The Low Divergence/Low Activity condition supports findings that modeling a low level of divergent thinking decreases exploration in 4- to 9-year-olds (Bonawitz et al., 2011; Carr et al., 2015; Wood et al., 2013). However, interestingly, this was not the case for the Low Divergence/High Activity condition. One possibility is that both divergence and activity levels are important in encouraging divergent thinking.

We propose three ways in which modeling a high level of divergent thinking could increase toddlers' divergent thinking compared to modeling a low level of divergent thinking. First, toddlers may have felt permitted and/or encouraged to explore. Second, toddlers may have learned more about objects' features when shown high levels of divergent thinking. They could use this information to produce novel action-box area combinations they would not have otherwise considered (Legare & Nielsen, 2015). This possibility could help explain the moderate divergent thinking scores in the Low Divergence/High Activity condition. While children could only learn five action types to recombine, they learned them well (as demonstrated by the highest imitation scores in this condition), and so perhaps had a better chance to combine them compared to the other conditions which showed actions only once. Third, children could have imitated the experimenter at an abstract level – copying their high level of divergent thinking, rather than their specific actions.

Alternatively, perhaps children in the High Divergence/High Activity condition produced more novel actions because they made mistakes while trying to imitate the experimenter, or they resorted to emulation rather than imitation, that is, finding their own solution to produce the same goal (Horner & Whiten, 2005). It may have been difficult to imitate as they saw five actions on each trial. However, children in the Low Divergence/Low Activity condition imitated only around 34% of the time, even though they needed only focus on one action per trial. This suggests imitation was not their primary goal, especially considering that they produced substantially more novel actions in both conditions. Even if it was their goal, and they were making mistakes or emulating half the time (contrary to most imitation research) (Carpenter, Akhtar, & Tomasello, 1998; Meltzoff, 1995), we would expect an increase in divergent thinking, via mistakes or emulation, in the Low Divergence/Low Activity condition as well. However, future research could examine this more thoroughly by having an experimenter model actions on one version of the UBT with one set of novel objects, and having children interact with a different version of the UBT with a different set of novel objects. Since imitation could not occur, this would rule out the possibility of failed imitation or emulation.

This research provides a potential intervention to increase divergent thinking in toddlers. Modeling a high level of divergent thinking to young children could be a beneficial educational strategy, especially as toddlers' neuro-development is still highly plastic (Fox et al., 1994; Joseph, 1999). Since children's divergent thinking at 7 years predicts their future personal and career-related creative achievements as much as 50 years later (Cramond et al., 2005; Plucker, 1999; Runco et al., 2010; Torrance, 1981a), finding new ways to increase divergent thinking early on could be advantageous for society. Future research should replicate the current study using a baseline in order to determine whether this would be an effective intervention, and whether it would work equally well for children who initially have low or high divergent thinking levels. Furthermore, while divergent thinking interventions with older children have been effective, the longest time between training and testing was one week (Lee et al., 2007). Although this study suggests that divergent thinking training can go beyond immediate effects, it would be desirable to look at interventions on a more long term basis, such as several months.

One study which suggests modeling high levels of divergent thinking day to day could be an effective long term strategy is that by Hoicka et al. (2016) which found that parents' and toddlers' divergent thinking scores correlate well. Parents who are high divergent thinkers might exhibit more high divergent thinking behaviors for their toddlers, and toddlers might learn they are permitted and encouraged to explore the world. Alternatively, parents who are high divergent thinkers may highlight more features of the world that children can learn about, and combine this with their previous knowledge base to make new discoveries on their own. Finally, parents who are high divergent thinkers might teach their children, at an abstract level, how to think divergently. Future research should examine how intense, and how long, training should be to produce changes in children's underlying divergent thinking abilities.

Theoretical models (Legare & Nielsen, 2015; Mesoudi et al., 2004) and computational simulations (Rendell et al., 2010) appear to consider social learning and innovation as separate processes within cultural evolution. While they point out that one can use social learning as a basis for innovation, and that new innovations can be socially learned, they do not consider how social learning might increase innovative thinking more directly. However, Galef (2013) has suggested that for birds to learn songs, we must consider the interplay of both individual and social learning. This could hold true for humans as well. Future models should examine the interplay between innovation and social learning to a greater extent. In particular, they should consider whether individuals' own innovative abilities can be affected by the quality of divergent thinking that they witness in others.

Imitation versus Divergent Thinking

Unlike past research with goal-oriented tasks (Bonawitz et al., 2011; Carr et al., 2015; Wood et al., 2013), across modeling conditions, all children produced more novel than imitated actions, and children were more likely to produce at least multiple novel actions than any imitated actions. This is surprising as research shows that children from 3 to 7 years are very poor at innovating novel tools, but excellent at imitating the production of novel tools (Beck, Apperly, Chappell, Guthrie, & Cutting, 2011; Cutting, Apperly, & Beck, 2011; Cutting, Apperly, Chappell, & Beck, 2014). These findings could be because our task was open-ended, rather than goal-oriented and requiring problem solving, creating a different framework for learning. With an open-ended task, children may be more likely to think divergently than imitate since they may perceive there is no “right” or “wrong” answer. This interpretation converges with research suggesting toddlers are great explorers when tasks are open-ended (Bijvoet-van den Berg & Hoicka, 2014; Hoicka et al., 2016; van Schijndel, Franse, & Raijmakers, 2010; van Schijndel, Singer, van der Maas, & Raijmakers, 2010). This also converges with theory suggesting that in some situations, it is better to rely on individual rather than social learning (Giraldeau, Valone, & Templeton, 2002).

Alternatively, as children in our task were younger than in previous research, this could be due to age effects. Perhaps younger children are less likely to view a demonstration as an invitation to imitate at the expense of exploration. Future research should explore effects of object design and age in more detail.

A final possibility is that in the Low Divergence/Low Activity condition, by showing five different actions across the task, one with each object, we modeled a higher level of divergent thinking than these other tasks, even if the level of divergent thinking was not very high. Perhaps showing only one action on the box across the entire study would have yielded different results.

Some current dominant theoretical frameworks view toddlers as primarily social learners (Csibra & Gergely, 2006; Tomasello, 2009). However, the vast majority of studies on imitation have not reported the actions children create themselves (Carpenter et al., 1998; Gergely, Bekkering, & Kiraly, 2002; Hilbrink, Sakkalou, Ellis-Davies, Fowler, & Gattis, 2013; Horner & Whiten, 2005; Lyons, Young, & Keil, 2007; Meltzoff, 1995), perhaps not providing a clear view of all the learning processes at play. Future research on social learning should consider the role of producing novel acts.

Finally, no correlation between toddlers' imitation and divergent thinking was found. Therefore even though older children are less likely to innovate once they have an opportunity to imitate (Carr et al., 2015) this is not necessarily the case for 2-year-olds in an open-ended context. Future research should explore the relationship, or lack thereof, between individual differences in imitation and divergent thinking more thoroughly. For instance, future research could compare scores on separate imitation and divergent thinking tests.

Conclusions and Future Directions

This research found that 2-year-olds can socially learn to think divergently. If an experimenter modeled a high level of divergent thinking, toddlers showed a higher level of divergent thinking themselves than children who saw a low level of divergent thinking combined with a low activity level. Additionally, all children produced more novel than imitated actions in the modeling conditions, even in the Low Divergence conditions. This suggests children are not just imitators – they also generate their own ideas. Future research should examine the interplay between individual differences in children's divergent thinking and imitation, and modeling high levels of divergent thinking to them. Future research should also examine whether modeling high levels of divergent thinking has long term effects on toddlers' divergent thinking. Finally, theoretical models and computational simulations should consider how witnessing various levels of divergent thinking in others affects innovation.

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Appendix A

Actions modeled for toddlers

Shaker

-Touch room

-Hit side of box

-Turn on the blocks

-Drop on stairs

-Cover hoop

Rubber Toy

-Push round hole

-Jump on edge of box

-Walk on blocks

-Pull round hole

-Roll on stairs

Spiral-Shaped Egg Holder

-Touch rings

-Jump on blocks

-Push edge of box

-Shake in round hole

-Hit strings

Spatula

-Shake in square room

-Jump on stairs

-Hit rings

-Place in round hole

-Hold in place on strings

Plastic Hook

-Pull rings

-Place on edge of box

-Hold in place in round hole

-Hit blocks

-Push strings