Psychological distance and children's innovative problem solving

Sarah R. Beck (s.r.beck@bham.ac.uk)
School of Psychology, University of Birmingham, Birmingham, UK

Clare L. Whalley
School of Psychology, University of Birmingham, Birmingham, UK

Sabbi Lagaha
School of Psychology, University of Birmingham, Birmingham, UK

Ian A. Apperly (i.a.apperly@bham.ac.uk)
School of Psychology, University of Birmingham, Birmingham, UK

Jackie M Chappell (j.chappell@bham.ac.uk)
School of Biosciences, University of Birmingham, Birmingham, UK

Louise Taylor Bunce (louise.e.taylor@brookes.ac.uk)
Department of Sport, Health Sciences and Social Work, Oxford Brookes University, Oxford,

Abstract

Children find tool innovation difficult until they are around 8-years-old, despite being prolific tool users and imaginative. We drew on Construal Level Theory to test whether a spatial distance prime could improve children's performance. In three experiments we found evidence that performance did improve when children were primed to think in an abstract way (Experiments 1 and 2). We examined an alternative explanation that the effect arose through positive mood induction, but found no evidence for this (Experiment 3). Overall, our findings inform us about how children's innovation might be supported, and are one of few findings showing that psychological distance has impact on children's thinking.

Keywords: Problem solving; innovation; tools; physical cognition; cognitive development; psychological distance; construal level theory

Introduction

While young children are generally viewed as creative and imaginative in some areas (e.g. pretend play), they show remarkable limitations in their ability to solve novel physical-cognition problems. The most used tool-innovation test, the hook-making task, presents participants with a tall transparent tube and a bucket containing a reward in its base. Participants have access to a pliable wire (often a pipecleaner) that needs to be bent into a hook before it can be used effectively to retrieve the bucket and gain the reward. Inspired by observations that corvids can solve this task (Weir, Chappell, & Kacelnik, 2002) and subsequently cockatoos and nonhuman great apes (Laumer, Bugnyar, Reber & Auersperg, 2017 and Laumer, Call, Bugnyar, & Auersperg, 2018, respectively), a study of human children found that the majority succeed only from eight years old, with success between 33 and 55% at five to six years (Beck et al., 2011).

Children's late developing tool innovation contrasts with their propensity to use tools (e.g. spoons, iPads) from a very young age (van Leeuwen, Smitsman & van Leeuwen, 1994), as well as their apparent creativity. One theoretical interpretation of this is that our species has evolved to prioritize learning from others in early childhood, postponing innovative behavior to later in development. Another approach has been to try to identify the cognitive or social factors that make tool innovation difficult for young children. This has been a productive line of research: children's poor performance does not improve when they are given explicit permission to manipulate the materials, shown that pipecleaners are pliable, or freed from any social pressure and left to solve the task on their own (Whalley, Cutting, & Beck, 2017; Cutting, Apperly, Chappell, & Beck, in prep.). Furthermore, attempts to link tool-innovation performance with measures of executive function or broad measures of creativity have not found correlations (although one study suggests that performance is linked to hierarchical reasoning Gönül, Takmaz,, Hohenberger, & Corballis, M., 2018).

Here, we take a new approach to understanding tool innovation, by testing whether the context in which children encounter a problem impacts their success. Some evidence to support this comes from observations that when presented with the task in a much freer museum environment, younger children (from 4-5 years) have more success with the hook task (Sheridan, Konopasky, Kirkwood, & Defeyter, 2016). We turned to the literature on psychological distance which suggested that creativity could be improved.

Construal level theory (CLT) defines psychological distance as "a subjective experience that something is close or far away from the self, here and now" (Trope & Liberman, 2010, p. 440). An event is more psychologically distant the further it takes place in the past or future (temporally distant), the more distant the location in which is takes place (spatially distant) and when the event is increasingly unlikely to occur (distant in terms of hypotheticality).

CLT asserts that as psychological distance increases, construals become more abstract. Likewise, as the level of abstraction increases, the psychological distance that a person experiences also increases. It is thought that construal levels can broaden and narrow our mental horizon, allowing us to represent and experience things in an increasingly abstract or concrete way (Trope & Liberman, 2010). Individuals represent proximate events using more concrete (low-level) construals and distant events using more abstract (high-level) construals (Liberman & Trope, 1998). For example, when asked to describe the act of "cleaning the house" in the distant future, it is more frequently described in terms of the abstract overall goal e.g. "showing cleanliness", whilst in the near future, participants more often described the concrete means of achieving the goal e.g. "vacuuming the floor."

Few studies have explored the effects of psychological distance from a developmental perspective. Of these, some have shown that young children can benefit when psychological distance is created in an experimental setting. For example, children are better at delaying gratification when they are encouraged to mentally transform an appetising reward (e.g. marshmallows) into a more neutral object (e.g. a fluffy cloud) (Mischel & Baker, 1975).

Distancing from the self has also shown to improve children's executive function (White & Carlson, 2016). Five-year-olds completed the Minnesota Executive Function Scale for Early Childhood, a seven-level card sorting task (Carlson & Schaefer, 2012), whilst taking on perspectives that varied in distance from the self. Performance improved when children were instructed to speak to themselves in the third person when it became difficult e.g. "I want you to ask yourself, "Where does [child's name] think this card should go?"' or when taking on the perspective of another character e.g. "In this game, I want you to ask yourself, "Where does [Batman] think this card should go?"' (White & Carlson, 2016).

We know from adult studies that temporal distancing affected participants' performance on insight problems and creativity tasks (Forster, Friedman, & Liberman, 2004), likely because abstract thinking, as implicated in high-level construals has been associated with enhanced creativity (Ward, 1995). Liberman, Polack, Hameiri and Blumenfeld (2012) manipulated spatial distance by showing 6- to 9- year old children a series of photographs. In the distancing condition, they were shown photos from the very near (a zoomed-in picture of their pencil on their school desk) to increasingly distant perspectives (the classroom, the school building, the local area right up to the final picture of the Milky Way). In the proximity condition, children saw the same pictures, but in the reverse order from the very distant (the Milky Way) to the proximal (pencil on their school desk). Following this spatial distance priming exercise, children completed the Tel Aviv Creativity Test (TACT) as a measure of their creative performance. Children in the distancing condition produced significantly more ideas on the creativity test and were more original in their responses, compared with children in the proximal condition. This finding was the first to demonstrate the effect of spatial distancing on abstract mental construals in children, demonstrating that this effect is present by the time they reach early school age. The implications of this study are significant, suggesting that children's creativity can be improved by a simple task encouraging abstract thought.

Given the benefits children have reaped from self-distancing in relation to their goal-directed action (Mischel & Baker, 1975; White & Carlson, 2016) and spatial distancing in relation to their creative performance (Liberman et al, 2012), we investigated whether the findings of Liberman et al (2012) might extend to a novel tool-innovation task (Hooks task). At present, it is unclear whether children's tool innovation performance could be enhanced by encouraging them to think in a more abstract way. Creative problem solving requires individuals to produce novel problem solutions (Mumford et al, 1991), rather than relying on previously acquired solutions. With this in mind, the Hooks task requires creative problem-solving, including tool innovation. It is possible that priming children to think in a more abstract way which primes creativity, could improve their tool innovation on the Hooks task. It is also possible that solving innovative tool problems such as the Hooks task, where there is only one correct solution, is more reliant on a more concrete, convergent style of thinking. If this were the case, priming abstract or divergent thinking might not benefit innovation.

Experiment 1

In the first study, we investigated whether children's performance on the Hooks task was affected by spatial distance priming. In two conditions, children were either exposed to spatial distance priming from the near to far (Distancing) or from the far to near (Proximity). In an attempt to replicate the findings of Liberman et al (2012), children then completed a creativity measure as well as the Hooks task.

Method

Participants

Ninety-eight children (52 boys and 46 girls) aged 5- to 7-years (Mean = 6;8, Range = 5;7 – 7;6) participated from one mainstream school in the UK. There were forty-one 5- to younger 6-year-olds and fifty-seven older 6- to 7-year-olds. The ethnic composition of the sample was not recorded.

Materials

Spatial Distance Priming (SDP): The priming procedure was that used by Liberman et al (2012), in which stimuli of increasing spatial distance are presented on a laptop screen. The proximal stimuli consisted of pictures taken at the participants' school. Distal stimuli were pictures which were downloaded from the internet. The 16 pictures presented were (in order from proximal to distal): a pencil on a desk, a pencil and a pencil case on a desk, a desk, a classroom, a classroom door, the school building, the school's street, a map of the school's local area, a wider area map, a regional map, a UK map, a world map, the Earth from space, the solar system and the Milky Way.

Creativity test: To measure creativity, children completed a task adapted from Milgram, Milgram and Landau's (1974) Tel Aviv Creativity Test (TACT). The TACT is itself an adaptation of Wallach and Kogan's (1965) creativity test and has been widely used with samples of children as a valid measure of creativity. Like previous studies (e.g. Ziv & Keydar, 2009; Liberman et al, 2012) we used a shortened version of the test, to ensure that the total testing time was appropriate. Children were asked four questions and asked to produce as many ideas as possible. This included two verbal, "different uses" items ("What are all of the different things you can do with a shoe?" and "What are all of the different things you can do with a chair?"). and two visual "meanings of shapes" items ("What are all of the things this shape could be?"). For the visual items, the shapes (a circle and a square) were presented on a laptop screen placed in front of the child. Data was coded on two levels: fluency and originality. Fluency was the total number of responses children made. Original items were those which were made by fewer than 5% of the overall sample. The participant's number of original items was divided by their total number of responses to produce an originality score.

Hooks Task: The apparatus was a transparent plastic tube (30cm length; opening 4cm in diameter) attached to wooden base (55cm x 55cm). At the bottom of the tube there was a small bucket containing a sticker. The bucket had a wire handle which required a hook to retrieve it from the tube (See Figure 1).

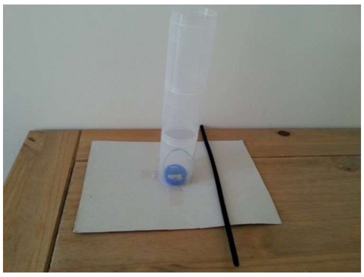

Figure 1: Hooks task apparatus

Procedure

Children were sat in a quiet area outside their classroom, at a table next to an experimenter. All children completed the spatial distance priming first. Children were allocated to one of two spatial distance primes: in the Proximity condition, priming pictures were presented from distal to proximal (Milky Way to pencil), in the Distancing condition, priming pictures were presented in reverse (pencil to Milky Way). Half of children in each priming condition then completed the Hooks Task, followed by the Creativity Task (Distancing Hooks-Creativity (HC) and Proximity HC). The other half of children in each condition completed the Creativity Task, followed by the Hooks Task (Distancing Creativity-Hooks (CH) and Proximity CH).

Next, children completed the Hooks and Creativity Tasks in the order according to their condition. In the Hooks Task, the tube apparatus was placed on the table, directly in front of the child with the pipecleaner placed next to it (see Fig. 1). Children were told that if they were able to retrieve the bucket from the tube, they could keep the sticker. The experimenter then pointed out a straight 30cm pipecleaner placed next to the apparatus and told the child: "Here is something that can help you. You can try anything you like." Children were given up to 2 minutes to complete the task. When children stopped engaging with the task, neutral prompts were given. If a child failed to make a hook after two minutes, they were asked a final time "Is there anything else that you would like to try?" Children were given a further 30 seconds if they wanted to attempt again. Following this, the trial was ended. Children who failed to make a hook of their own were given a premade hook in order to retrieve the sticker.

In the Creativity Task, children were given the opportunity to take part in an activity to win another sticker. They were advised that they were going to be asked a series of questions and that they should try to come up with as many different ideas as they could. Children were asked the questions in a fixed order and were given one minute for each item, to produce as many ideas as possible. Their responses were recorded on a Dictaphone and live by the experimenter. All children received a sticker at the end of the activity.

Results

There were no effects of gender on either of the tasks (lowest p = .181), therefore all data were collapsed into one sample. Descriptive statistics for the creativity task are presented in Table 1 below.

Table 1: Children's performance on the Creativity Task in Experiment 1.

	Mean	Minimum Score	Maximum Score
Fluency (total number of responses)	18.28	7	28
Originality (proportion of original responses)	9.95	0	.93

Performance on Creativity Test

A three-way analysis of variance (ANOVA) examined the effect of direction of spatial distance priming (Distancing/Proximity), task order (Hooks task first or second) and school year group on fluency (the total number of creativity items produced). This yielded no significant main effects or interactions (highest $F = 1.42$, lowest $p = .24$).

A three-way ANOVA examined the effect of direction of spatial distance priming (Distancing/Proximity), task order (Hooks task first or second) and school year group on originality (proportion of responses produced that were produced by less than 5% of the sample) in the creativity measure. This also yielded no significant main effects or interactions (highest F = 2.39, lowest p = .126).

Performance on Hooks Task

Success on the Hooks task was defined as making a functional hook, regardless of whether the child managed to successfully retrieve the bucket from the tube. A functional hook was defined as one of an appropriate size to make retrieving the bucket possible. This success criterion was implemented in order to avoid underestimating rates of innovation.

Table 2 shows the frequency of success on the Hooks task in Experiment 1 by condition. Chi-squared analysis had revealed no significant effects of age on success on the Hooks task χ^2 (1, 98) = 2.38, p = .123. However, for completeness and for the purposes of comparison with the sample used by Liberman et al (2012), we analysed the two age groups separately (5- to 6- year-olds and 6- to 7- year-olds. Across 4 conditions, Freeman-Halton Extensions of Fisher's Exact Test showed no significant effect of experimental condition on Hooks Task success in 5- to 6- year-olds (n = 41, p = .789) and a significant effect of experimental condition on Hooks task success in 6- to 7- year-olds (n = 57, p = .038).

Post-hoc comparisons were run to establish which conditions were significantly different from one another for 6- to 7- year-olds, starting with the conditions where performance was most different. To avoid Type I Error, a Bonferroni correction was conducted based on the total number of possible comparisons that could be made (6, $\alpha_{altered}$ = .008). Children performed best on the hook-making task in Distancing CH and least well in Proximity HC and therefore this was the first comparison run. Children were significantly better at the Hooks task in Distancing CH compared with Proximity HC, χ^2 (1, 28) = 7.34, p = .007.

Table 2: Children's performance on the Hooks Task in Experiment 1

Age group	Condition (n)	Success on hooks task	Failure on hooks task
5-6	Distance HC (10)	5	5
	Distance CH (11)	7	4
	Proximal HC (10)	5	5
	Proximal CH (10)	4	6
6-7	Distance HC (15)	11	4
	Distance CH (14)	12	2
	Proximal HC (14)	5	9
	Proximal CH (14)	10	4

Although the comparisons between Proximity HC, Distancing HC and Proximity CH failed to reach the Bonferroni corrected significance value (smallest *p* = 0.42), it is worth noting that children's performance on the Proximity HC condition appears different to the other three conditions when examining the raw data, and that the performance of one or two children has a large impact on the statistical tests. Therefore, we concluded that the priming manipulations may have some effect on tool innovation and investigated this further in future studies.

Discussion

We found that 5- to 7-year-olds' performance on the creativity measure was not affected by the distancing manipulation. We failed to replicate the finding that spatial distancing improves fluency and originality on a creativity measure (Liberman et al., 2012). Although our creativity measure included some of the same items as those used by Liberman et al (2012), it was not identical and contained fewer items. It is possible this is the reason we failed to replicate their original finding. Despite this, our findings raise concerns about the robustness of spatial distance priming on this type of creativity task. As our main focus was on children's innovation, we did not explore this discrepancy further.

We found that 5- to 6-year-olds' tool innovation was not affected by SDP condition, or the order of task presentation (whether they completed the creativity measure before or after the tool innovation measure). Whilst it is possible that SDP does not affect tool innovation in this age group, it is also possible that the younger children were not as familiar with the stimuli used in the priming task. Since no effects were observed in this age group and given that Liberman et al (2012) did not use their spatial priming measure with children younger than 6, subsequent studies focused on 6- to 7- year olds.

In Experiment 1, the worst performing 6- to 7-year-olds were in the proximal HC condition. Performance by the Proximal CH group was no different to the Distance priming conditions. Was it possible that the creativity task that children had completed before the hooks task in this condition (Proximal CH) also acted as a prime? In our second study, we removed the complication of the creativity task and we introduced an additional baseline condition which was essential if we were to judge whether children's performance was being enhanced by distance priming.

Experiment 2

Method

Participants

The participants were 56 children (30 girls and 26 boys) aged 6- to 7- years (M = 6;11, R = 6;5– 7;4) from one mainstream school in the UK. The ethnic composition of the sample was not recorded.

Materials

Priming of spatial distance: The priming procedure was the same as in Experiment 1, although some of the picture stimuli were changed e.g. the classroom, school and local area, to be relevant to the children in this sample.

Hooks Task: The apparatus from Experiment 1 was used.

Procedure

Children were sat in a quiet area outside of their classroom, next to an experimenter who live coded the experiment. A second coder was present at 25% of test trials and agreement on successful hook innovation between the coders was 100%.

Children were allocated to one of three conditions: Distance, Proximal or Baseline. During the first phase of the experiment, children were shown a series of images on a computer screen. All children saw the same images, although the order of their presentation was manipulated by their experimental condition. The Distance and Proximal conditions were the same as Experiment 1. In the new Baseline condition, pictures were randomized. Following the pictures, all children completed the Hooks task.

Results

Success on the Hooks task was defined as making a functional hook, regardless of whether the bucket was retrieved within the given time limits. There was a significant effect of gender (boys more successful than girls) on hook making, χ^2 (1, 56) = 4.60, p = .032. However, the opposite gender effect has been observed previously (Walley, Cutting, & Beck, 2017). These findings are noted for future investigations on gender differences and problem solving. However, as this task has been run many times without significant effects of gender being observed, they will not be discussed further.

Performance across conditions is shown in Table 3 below. Children in the Distancing condition showed the greatest success on the Hooks task. An omnibus Chi Square comparing performance on the three conditions was significant, χ^2 (1, 56) = 16.95, p < .001. We then ran post hoc Chi Squares to compare performance on pairs of conditions, using a Bonferroni correction ($\alpha_{altered}$ = .017). Children in the Distancing condition were significantly better at innovating a hook than those in the Baseline condition, χ^2 (1, 37) = 16.88, p = <.001 and in the Proximal condition, χ^2 (1, 38) = 5.73, p = .017.

Although it appeared in the raw data that more children were successful in the Proximal condition compared with the Baseline condition, this failed to reach the Bonferroni corrected p-value for significance, χ^2 (1, 37) = 3.98, p = .046.

Table 3: Performance on the Hooks task in Experiment 2

Condition (n)	Success on Hooks task	Failure on Hooks task
Distancing (19)	16	3
Proximal (19)	9	10
Baseline (18)	3	15

Discussion

Children were more successful at tool innovation following spatial distancing compared with the proximal priming and baseline conditions. This suggests that spatial distancing improves children's tool innovation performance. According to construal level theory, this is because the distance priming leads children to think in a more abstract and creative way. If this is the mechanism by which children are successful, it also suggests that success on the tool innovation task is underpinned by abstract and creative thinking.

Before we accepted this, we tested an alternative mechanism that may explain children's success, partly because of our own concerns that the SDP account still seemed quite vague. A separate literature suggests that positive mood improves performance on creativity tasks. Russ and Kaugars (2001) found that children who had made a puppet do something that made them happy thought of more alternative uses for an object that those who had made the puppet behave negatively. Other studies have also shown that positive mood increases originality (Greene & Noice, 1988; Isen, Daubman & Nowicki, 1987).

We were intrigued by this alternative mood account first because, despite the lack of significant difference, children had performed worst in the baseline condition (rather than in between the two SDP conditions). Was it possible that seeing pictures in a random order was unpredictable and confusing? We then speculated that the distance condition where children start with pictures of objects in the classroom and end with the Milky Way may have been predictable and engaging as they would have understood the progression of the pictures. It is possible that the half of the pictures that were maps and space photos did not convey the pattern as effectively as the school photos and may also have been confusing when viewed first in the Proximal condition. These observations were speculative, but prompted a final experiment where we sought to replicate the SDP effect on tool innovation and test whether similar effects could be seen with a mood induction.

Experiment 3

Method

Participants

One-hundred children aged between 5-7 years old (54 boys and 46 girls) were recruited from a primary school in the United Kingdom. 81% were Asian, 10% Caucasian and 9% Afro-Caribbean. There were two age groups: Younger children (29 boys and 24 girls, M = 5;9, R = 5;6 – 6;1) and older children (25 boys and 22 girls, M = 6;8, R = 6;2 – 7;9).

Measures and Materials

Spatial Distance Priming Task (SDP): We used the same SDP as in previous experiments.

Positive Mood Induction Task: Children were asked to describe a positive memory for thirty seconds. "In this game, I'd like you to think of something that makes you so happy you just want to jump up and down. It can be of a birthday or a fun day out. Can you tell me all about it?"

Neutral Mood Induction Task: In neutral mood induction task two, participants were presented with a water bottle and told 'In this game, I'd like you to think about this. Can you describe it for me please?"

Hook Making Task: The same hook making task was used as in Experiments 1 and 2.

Procedure

Children in the mood induction conditions completed their description task before attempting the hooks task. The SDP condition saw the picture primes before the hooks task. The baseline condition were just presented with the hooks task.

Results and Discussion

No gender differences were found in performance on the hooks task (p = .34). Performance on the hooks task is summarized in Table 4.

An omnibus Chi-square test of independence showed a significant effect of condition was found χ^2 (3) = 7.8, p = .05. However, none of the post hoc Chi-square tests comparing conditions proved significant, with the Bonferroni corrected α value (α = .008).

Treating the two age groups separately, there were no differences between conditions.

Table 4: Performance on the Hooks task in Experiment 3

		Hook task success	Hook Task failure
5-6 year olds	Positive mood	4	10
	Negative mood	4	10
	SDP	6	7
	Baseline	2	10
6-7 year olds	Positive mood	2	9
	Negative mood	2	9
	SDP	7	5
	Baseline	3	10

We found no indication of any impact of mood on problem solving (positive or negative). Our only significant finding (the omnibus Chi Square test) although a weak result, can only be attributed to the better performance by the SDP condition compared to either mood condition or the baseline.

General Discussion

In three studies we examined whether children's tool innovation was affected by the context in which they encountered the problem, specifically whether we could prime them using spatial distancing to think in an abstract way and solve the task. In Experiment 1 we found a suggestion that priming with spatial distance (moving from near to far examples) resulted in a larger number of children solving the tool innovation task. We confirmed this finding in Experiment 2, where we also included a baseline measure. Finally, in Experiment 3 we tested whether the effect of spatial distancing might instead result from positive mood. However, there was no evidence for this. In conclusion, we found evidence that spatial distancing priming can influence children's creative problem solving and that children can be supported to innovate.

We note that we did not replicate the original finding from Liberman et al. (2012). In Experiment 1 there was no difference on the creativity task between children who had the distance or proximal primes. We considered that this may have been due to small differences between our creativity task and the original, although this would indicate that the effect is rather fragile. We had a larger sample size than in the original study, however, the oldest children in our study were 6-7 while Liberman et al. (2012) included children up to 9 in their sample. It is likely then that this priming effect is stronger in older children and this should be explored in further research.

Finding that the Hook-making task can be supported by priming abstract thinking could advance our thinking about tool innovation. Earlier we speculated that it was to our species' evolutionary advantage to focus on learning from others at a young age. One way this might come about is by children focusing on the concrete at an earlier age before developing more abstract though that could support innovation with time. Of course, this fits with a broadly Piagetian position that children progress from concrete to abstract thought. Furthermore, in studies of children's tool innovation it is unexplained why some children pass tests before their peers (around a third of 5-year-olds, for example). This has not been explained by gender or various cognitive abilities, but perhaps some children might be more inclined to think in an abstract way. Related to this, future research should also explore the reliability of these findings, beginning with testing whether other ways of priming psychological distance (e.g. temporal and social) also increase innovation. Future research could also include a manipulation check to examine children's experience of the sense of distance and should use the findings in these studies to inform power calculations for sample size.

Our developmental findings are important for understanding psychological distance and construal level theory where it originates. We provide the second evidence that a spatial distance prime can influence children's thinking and behavior. One advantage of cognitive developmental work is that by testing children at different ages as other abilities emerge, we can learn more about the mechanisms underpinning complex thought. In our studies there is some evidence that younger children, around 5 years old, were less affected by the SDP. Why this might be and whether the effects increase or otherwise change with age will offer new insight into how SDP works.

Perhaps the most important conclusion to draw from our studies is that we find that children (at least from around 6 years) can be helped to solve tool innovation problems if the context in which they encounter them is changed. This is in keeping with other recent findings that suggest giving children much longer to complete the task also increases success (Voigt, Pauen, & Bechtel-Kuehne, 2019). Children remain poor innovators, but this way of thinking can be recruited given the right circumstances.

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