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# Creating Creativity: A Behavior Analytic Approach

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**Abstract**
Creativity and innovation have brought about phenomenal changes throughout human history. Art, science, medicine, industry, and technology have all grown through creative and innovative behavior. A complete science of human behavior needs to account for "creativity," especially given its importance in society. Prior behavioral research has been able to account for creative behavior in animals by training the component skills of a complex creative solution and arranging environmental conditions which result in the recombination of component skills to produce a creative solution. The present study partially replicates creativity research conducted in a laboratory setting with animals by conducting a similarly arranged laboratory study with humans. The purpose of the present study was to determine whether a creative solution to a difficult problem could be produced by teaching participants the necessary component skills and arranging the environment in such a way as to cause the component skills to recombine in order to solve the problem. The present study suggests that such an approach may be viable and provides an experimental task that can be used in future human creativity research.

**Keywords** creativity · innovation

## Defining Creativity

What is creativity? This seemingly simple question has plagued artists, scholars, and even mid-level managers. Although answers will vary, most basic definitions seem to contain two elements: (1) the emergence of a novel product and (2) the product having value to an individual or group of individuals (Ripple, 1989; Stein, 1953; Sternberg & Lubart, 1996). If only the first element is present, then there is a new, but not a valuable, product. For example, if a person took 30 s and wrote a string of random words and nonsense words this would be a rather novel string of babble, but it would likely be of little to no value to anyone. One would be hard pressed to read the string of babble and label it as creative. If only the second element of creativity is present, then there is a valuable, but not a new, product. For example, if an individual spent 30 s to copy a few lines from a famous poem, some people might say the replication of the poem has limited value but copying words someone else has written would unlikely be called creative by anyone.

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"Creativity" involves large segments of operant behavior. In addition, the controlling variables that lead to an observer of the creative performance labeling the performance as creative must be considered. As such, creativity cannot be defined by only referencing a simple topography. The performance has to be novel to society at large or at least novel relative to one's behavioral history. It would be overly difficult, if not impossible, to provide a comprehensive and clear definition that would be agreeable to everyone. However, a perfectly agreeable definition is not necessary for a functional analysis of creative behavior. When a behavior is said to be creative, the controlling variables that evoke such a label can be determined without a definition of creativity being determined in advance (Epstein, 1980).

An observer's behavior of labeling something as "creative" is influenced by multiple variables. Two of those variables are the saliency of control of a behavior and how people attribute value to a behavior. An observer would be more likely to label something as creative when the controlling variables for the behavior are unknown. For example, an observer listening to a new creative song may not be able to identify the thousands of hours of practice on the part of the musician, the genres of music the musician listened to, or the various musical styles the musician was trained in which combined to form the creative song. Likewise, when the controlling variables of a behavior are known, it would not likely be labeled as creative. A behavior that is imitated or the result of following instructions can lead to novel responding, but the control is usually obvious to the observer; thus the behavior is not considered to be creative. For example, if a musician listens to and imitates the new creative song, the imitated version would not be labeled as creative regardless of how well the song is imitated. A novel behavior, or its product, is only labeled creative if an observer considers it as having some value. Roughly speaking, a behavior or product has value to an observer if it has the potential to function as a reinforcer for the observer's behavior.

Several scholars have focused on a distinction in two general types of creativity: Big "C" and Little "c" creativity (Csikszentmihalyi, 1996; Kubina et al., 2006). Big "C" creativity is a term that describes the rare, highly notable creative products, such as Einstein's Theory of Relativity, Thomas Edison's electric light, or Mozart's musical works. Little "c" creativity refers to the more common and less notable acts of creativity, such as the invention of a picture frame, baby changing table, or elevator music. This distinction is not likely to be consistently reliable, but it does have some use in distinguishing between the great creative and innovative acts and products of history and the run-of-the mill creative acts and products produced on a daily basis. Marr (2003) made a similar distinction but used "genius" instead of "creativity." Genius connotes creativity or innovation and fits with the general language of creativity, although it also suggests some level of complex intellectual behavior.

Although the distinction between Big "C" and Little "c" is not a strict dichotomy, the distinction nonetheless falls in line with the common perception of creativity. Although imperfect, the Big "C" and Little "c" differentiation allows us to approach creativity in a manner that reflects how the general public talks about creativity (i.e., Big "C"). In much the same way, Skinner's definition of verbal behavior was not meant to provide an intrinsic distinction between verbal and nonverbal behavior. Rather, the purpose of the definition was to provide a structure to analyze behavior that has clear social significance (Skinner, 1957). The conceptualization of Big "C" creativity allows people to talk about most instances of what would be labeled as creative, even if the boundaries are imprecise. Such imprecision is to be expected because the social community uses the term inconsistently. It seems apparent that there is an everyday or common type of creativity and an extraordinary type of creativity. At one end, the Little "c" creativity is of interest and value, but at the other end the Big "C" creativity is of exponentially higher interest and value. The ability to explain, understand, predict, and control the latter type of creativity could help to effectively produce more Thomas Edisons, Albert Einsteins, and Steve Jobs. Although this may be an audacious claim, it is the hope that this research will contribute to a foundation for the development of a behavioral account of creativity.

## A Behavioral Approach to Creativity

As B. F. Skinner explained in "A Case History in Scientific Method" (1956), scientific advancements and innovations are often not the result of logical, formal, or mathematical practices. When referring to the scientist, Skinner writes, "The work habits which have become second nature to him have not been formalized by anyone, and he may feel that they possibly never will be" (p. 221). He claims that this is due in part to the difficulty to clearly verbalize scientific practices that lead to innovations. After all, part of the nature of a hunch is that it cannot be easily communicated. Given the lack of documentation for the processes underlying scientific advancement, Skinner called for an empirical approach rather than a more structured formal or logical approach.

Behavior analysis takes an empirical, natural scientific approach to the study of behavior. That is, behavior analysis focuses on actual controlling variables in the environment to account for behavior of organisms. Behavior analysis does not appeal to hypothetical constructs (e.g., we would not say that creative behavior happens because the person has a lot of creativity), or circular reasoning (e.g., creative behavior happens because the person is creative, and we know that person is creative because they engage in creative behavior). Most of creativity research has not adopted such an approach, but rather, has appealed to hypothetical constructs. For example, creativity is often thought of as being an innate characteristic that a person has; it cannot be taught, only brought out (Hennessey & Amabile, 2010). This approach suggests genetics would weigh heavily in determining creativity but downplays the importance of how the environment shapes behavioral development.

Phylogenic selection accounts for types of inherited behavior patterns or propensities. This type of selection results from the evolutionary history of a species along the lines of Darwinian evolution. Behavior analysis accounts for behavior through ontogenic forms of selectionism (Skinner, 1981). Ontogenic selection accounts for learned behavior through operant selection by consequences, which takes place continuously over the life of an organism (Cooper et al., 2007; Skinner, 1981). Operant selection provides a solution to the problem of development and diversity of behavior as natural selection did for a similar problem of development and diversity of species in evolutionary theory (Skinner, 1953). Cultural selection accounts for behavior of individuals from the verbal behavior and social contingencies provided by other members of the culture, which allows for learning without directly experiencing the conditions that generated the original learning (Glenn, 2004).

Ontogenic selection, in the form of reinforcement, is able to account for the increase in several dimensions of operant behavior including but not limited to response rate, intensity, and duration (Cooper et al., 2007). In addition to these relatively common dimensions of behavior, research has shown that reinforcement can increase other dimensions or characteristics of behavior, such as novelty. Eisenberger and Armeli (1997) demonstrated that novel performance, in the form of stating unusual uses for common physical objects, was sensitive to reinforcement. The authors found that not only was novelty a reinforceable dimension of behavior, but that it generalized to different tasks such as drawing pictures. Participants who received larger rewards for identifying unusual uses for everyday objects subsequently drew more novel pictures than participants in the low or no reward conditions. This finding contradicts previous studies that have claimed that reinforcement reduces creativity or novelty in responding (Amabile et al., 1986; Hennessey et al., 1989).

## Behavioral Research on Creativity

Behavior analysis has been used to train animals and people to increase their novel responding (Neuringer, 2004; Winston & Baker, 1985). In one study, porpoises were trained to engage in creative responding by differentially reinforcing novel responses (i.e., a response that had not been previously emitted). After training, the porpoises engaged in a wide range of variable and complex novel responses (Neuringer, 2004; Pryor et al., 1969). Several studies have also been conducted with pigeons in which the birds were trained to emit responses that simulated complex human behaviors such as symbolic communication, "self-awareness," and "insight"—which will be discussed below (Epstein, 1981). Of course, response variability has also been trained in humans through operant conditioning procedures (Neuringer, 1986). One of the largest contributions of a behavioral approach to creative behavior is the ways in which it is able to account for variability in responding (a necessary condition for creative performance). Of course, promoting variability also produces novelty, but not necessarily creativity (because the novel behavior may or may not be considered valuable to the social community). However, practices and procedures that regularly evoke novel responding will increase the probability that a variant of behavior that is considered valuable will eventually be emitted and thus will be considered creative due to being both novel and valued. This article will now consider several sources of behavioral novelty and by extension, potential sources for creativity.

### Reinforcement

Many studies conducted in laboratory settings with nonhumans and humans have shown that reinforcement reliably increases novelty and diversity of responses (Neuringer, 2004). Several applied studies have also demonstrated similar findings. In one such study, Lee and Sturmey (2006) used lag schedules of reinforcement to increase novelty and diversity in responding to a question. Children with autism were asked what they liked to do and received reinforcement when the response emitted was both appropriate and different from previous trials. This produced an increase in the diversity of appropriate responses. In another applied study (Goetz & Baer, 1973), the block-building behavior of preschool girls was analyzed and found to occur in largely the same forms across baseline sessions. The authors provided social reinforcement contingent on a participant building the blocks in a form that was not previously used in that session. Contingent reinforcement of constructing diverse block structures resulted in an increase in both the diversity and novelty of forms built in each session. On the other hand, when social reinforcement was provided for repetitive block structure forms, the number of novel forms built in each session decreased.

## Extinction

Extinction involves the discontinuation of reinforcement for a previously reinforced response resulting in a decreased rate of that response in the future. Extinction procedures can induce temporary variability in several response dimensions including frequency, intensity, and topography (Cooper et al., 2007). It is the variation in response topography that would be most readily labeled as novel responding.

## Imitation

Novel responding can be brought about via imitation. Imitation includes a modeled response seen or heard by an observer and the occurrence of the modeled response by the observer. Through imitation, observers can quickly engage in behavior that is novel to them. Such imitative responding is typically reinforced by either contact with natural sources of reinforcement (such as when someone successfully interacts with a new piece of technology after mimicking that actions of others currently using the technology) or through social reinforcement from others, perhaps from the model themselves (such as when a parent praises a child for correcting echoing a multisyllabic word that the parent just said). However, imitated behavior is not usually labeled as creative, likely due to the salient controlling variables (i.e., the modeled response).

## Instructions

Novel behavior can occur as the result of following instructions. When a speaker gives specific instructions to a listener, the listener is generally able to follow the instructions by completing a behavior or behavioral sequence. The instructed behavior is not always novel to the listener, but it often can be. Like imitation, novel behavior occurring as the result of following instructions is not likely to be considered as creative due to the obvious controlling variables (i.e., the instructions).

Exceptions can be found in cases for which the instructions were vague or general, likely due to the fact that the response products are not precisely predictable to a casual observer (e.g., it is difficult to know in advance what outcome will be produced by instructions such as "I want you to go to your office and think up a new strategy to deal with our budget shortfalls" or "I want you to show more passion in your performance next time"). In short, the more prescriptive the instructions, the less likely that rule following will be considered creative.

## Variation

Variability in responding naturally occurs in all operant behavior (Chance, 1999). As will be discussed in this article with generativity theory, all responses have some form of novelty or variation to them. Variation is often not considered to be creative, given that the observer saw previous instances of the response and the variation may have been slight, or was of no added value. However, there are times when variation in responding might be labeled creative.

In general, the processes discussed above would be considered Little "c" due to the triviality of the behaviors or the readily observable nature of the processes. The social community may be more likely to call the remaining techniques Big "C" creativity because the processes are difficult to directly observe. The unobservable nature of these processes leads the social community to label these forms of creativity as special. This is similar to B. F. Skinner's point regarding willpower from *Science and Human Behavior*: "It is natural that the 'will' as an inner explanation of behavior should have survived longer in the study of operant behavior, where the control exercised by the environment is more subtle and indirect" (Skinner, 1953, p. 112).

Owing to the subtle and indirect nature of such environmental variables, the verbal community tends to attribute causality to the individual or constructs within the individual, such as insight or creativity, rather than to the controlling environmental variables. Based on such common verbal practices, we will now modify our defining characteristics to include a third criterion beyond the standard considerations of novelty and value. We define creativity to be the occurrence of behavior that is (1) novel (either in form or in the conditions under which it occurs) or produces a novel product; (2) valued by the social community; and (3) produced by controlling variables that are not readily salient to the general social community (although the variables may be known to a more limited audience such as the scientific community). As such, the remaining techniques are more likely to be considered creative because of the subtlety of the controlling variables (the relevant historical events are often dispersed over time or involve multiple sources of control). Once again, these procedures do not guarantee creativity as the label of creativity depends upon the value assigned by the social community (which may not be consistent across audiences or time periods, such as when accomplishments are not appreciated until long after their production).

## Interconnection of Repertoires

A repertoire is a relatively stable tendency to perform in certain ways given certain environmental conditions due to the organism's behavioral history. A more colloquial way of expressing this would be to consider this tendency as a set of skills, although caution is warranted against mentalistic practices and reification with such expressions. The skills in a repertoire are related by environmental situations or settings (Cooper et al., 2007). For example, an individual could have one repertoire of skills for using a computer (e.g., typing, using a mouse, operating a word processing program, accessing the internet) and another repertoire for drawing using art supplies (e.g., sketching a layout, using a charcoal pencil, shading to display light and shadows). Behaviors that are part of a repertoire combine to produce novel and complex sequences of behavior over time. When behavioral tendencies that constitute a repertoire begin to interconnect, the products are more likely to be considered creative. This is due to the observer not being able to easily identify the controlling variables. One does not see such interconnection across a single session and therefore this process is not easily observable (Kubina et al., 2006). Research has shown that by isolating specific repertoires, their contribution to complex repertoires can be determined.

A study that Wolfgang Kohler conducted in the 1920s recorded instances of "insight" in the way chimpanzees solved problems. In this study, a banana was hung in a room out of reach of the chimpanzees. The room was empty with the exception of wooden crates, which were placed on the floor several feet away from the suspended banana. All six chimpanzees in the room tried jumping from the floor to reach the banana, but none was successful. After several minutes of trying, one chimpanzee paced the floor, then suddenly moved the box underneath the banana and in a fruitful effort, jumped from the box and grabbed the banana. The sudden emergence of an effective solution to this problem suggested that problem solving was not learned via trial-and-error and because of that it was argued that insight (or other similar hypothetical constructs such as creativity, innovation, etc.) was a necessary explanation to account for this observed performance (Kohler, 1925).

Nearly 60 years later, Epstein et al. (1984) conducted a study in an attempt to explain the insightful solution to obtaining the out-of-reach bananas. Epstein et al. suggested that the insightful response was due to a combination of component skills: pushing the box towards the banana and climbing on the box to reach the banana. Epstein et al.

replicated Kohler's earlier study using pigeons. Pigeons were selected as subjects because they do not naturally push boxes or other objects towards targets, nor do they typically jump on top of objects to reach food. Three targets were identified and trained: (1) directional pushing of the box; (2) climbing onto the box and pecking the suspended plastic banana which was paired with food; and (3) extinguishing flying and jumping towards the suspended plastic banana. Pigeons trained on all three component skills demonstrated a similar pattern of seemingly looking confused for several minutes and then suddenly pushing the box towards the suspended banana, hopping on the box and pecking the banana. All other pigeons that were trained on only two of the three targeted skills failed to solve the problem. Based on these findings, "a tentative, moment-to-moment account of a successful performance can be given" (p. 62). At the beginning of the problem-solving session, stimuli were present that controlled both box-pushing and banana pecking responses. These competing stimuli led the pigeons to engage in behaviors that the general population may label as "perplexed" or "confused." The pigeons did not fly towards the banana, because that response had been previously extinguished. The birds began pushing the box likely because the stimulus conditions closely resembled those of the directional pushing training condition; though the birds were only trained to push towards a green dot which was not present in the problem-solving condition, the pigeons were never trained to push towards the banana. Pushing the box in the direction of the banana only occurred in pigeons that were trained to peck the banana; in other words, "banana-directed pecks strengthened banana-directed pushes" (p. 62). Finally, the pigeons stopped pushing the box once it was located under the banana due to the process of autochaining. The box-under-banana stimulus condition controlled climbing and pecking responses. In other words, if given sufficient practice with the relevant skills, the emittance of one behavior would automatically create a set of conditions that made the subsequent behaviors (i.e., further pecks and climbing behaviors) more probable so that a solution emerged in the form of a continuous chained response.

## Autochaining

Automatic chaining, or *autochaining*, is the process by which a sequence of behavior emerges when one behavior produces a stimulus that increases the probability of another behavior (Epstein, 1997). For example, consider the Epstein et al. (1984) study discussed above. When the pigeon pushed the box, the box moved closer to the target. This slightly different, but new stimulus condition with the box closer to the banana served as a reinforcer, which strengthened pushing the box toward the banana. Likewise, pushing the box under the banana produced a situation where the pigeon could climb onto the box and peck the banana.

## Resurgence

Resurgence occurs when one response has been extinguished and an alternative response that was established undergoes an extinction procedure and the first, previously extinguished response reappears (Cleland et al., 2000). For example, consider the situation in which a person tells several one-line jokes that are reinforced with laughter from his friends. Once he has told all his one-line jokes to his friends they are no longer considered funny and no laughter follows. He then switches to telling the few story-based jokes he knows that are reinforced with his friends' laughter. Again, after the story jokes are told once they are no longer reinforced with laughter from his friends and the person reverts back to telling one-line jokes. The occurrence of previously reinforced behavior is not, in itself, creative. However, resurgence may contribute to behavioral creativity by making the recombination of behaviors more likely (Shahan & Chase, 2002).

## Contingency Adduction

Contingency adduction refers to when repertoires established under one set of contingencies are recruited by a differing set of conditions to produce a new behavioral relation (Andronis et al., 1997). As was the case for interconnection of repertoires, the current conditions necessitate a new performance in order to be successful. However, a defining distinction is that the new behavior is reinforced by a different effect on the environment. Once reinforced, the newly established behavioral relation becomes part of the individual's repertoire. As such, adduction with a particular contingency cannot be repeated with the same person (although it can be repeated across people as part of a training procedure), because once the behavior is emitted and reinforced it is no longer considered novel for that individual. Contingency adduction can involve the recruitment of a new sequence of behavior (linking previously emitted behaviors in a unique manner), new blend of existing behaviors (novel compound stimulus control resulting in a topographically unique response), a partial component of previously emitted behavior (as a result of new situation sharing some partial aspect of more familiar stimuli), derived relational control, and more (Johnson & Street, 2020).

When contingencies adduce, repertoires do not form an automatic chain as an interconnection; rather, a repertoire may be engaged by a different set of conditions into a new function and, over time, into an entirely new and different repertoire (Kubina et al., 2006). To illustrate, suppose another individual regularly engages in gardening as a hobby. While working on a marketing campaign at their advertising firm, the individual may recruit behavior established under one set of conditions to a new set of conditions, such as when they propose planting flower seeds by the roadside in the configuration of the company's logo. Because the new function (i.e., commercial/monetary gain) differs from the previous function (i.e., food or aesthetics), this novel proposal would be considered a form of contingency adduction. If the client valued the proposal, it would also be likely to be considered a creative marketing idea. Behavior that results from contingency adduction is more likely to be labeled as creative due to the fact that the controlling variables cannot be directly observed.

## Fluency

In order for skills to be most useful they need to be fluent. A fluent skill is one that has a rate that makes it effective in everyday life and can be readily performed after extended periods without practice. Fluency has also been shown to play a role in the emergence of novel behavior, especially in the interconnection of repertoires and contingency adduction. Fluency allows correct responses to be more readily emitted and therefore available for selection by consequences. Fluent skills are more readily able to be combined with other behaviors or repertoires in order to create new, complex behavioral sequences or repertoires that can be useful in solving problems (Johnson & Layng, 1992).

People with more extensive experiences with the aforementioned processes (e.g., diverse skills, regular emittance of novel behavior, fluency with component behaviors, connecting, blending, or extending behaviors and behavioral sequences) are more likely to emit behaviors that will eventually be called creative by others. This may be well summed up by a quote from an interview with Steve Jobs—cofounder of Apple and arguably considered one of the most creative and innovative people in the last century—regarding creativity (Wolf, 1996):

> Creativity is just connecting things. When you ask creative people how they did something, they feel a little guilty because they didn't really do it, they just saw something. It seemed obvious to them after a while. That's because they were able to connect experiences they've had and synthesize new things. And the reason they were able to do that was that they've had more experiences or they have thought more about their experiences than other people. (p. 163)

## Limitations and Goals

One of the largest limitations to a behavior analysis of creativity is that many of the processes responsible for producing novel responses, and thus creative behavior, often occur over an extended period of time, which is problematic if one wishes to compress events into a single research session. It is in the very nature of creative behavior that controlling variables are difficult to observe. That is to say, people tend to attribute the cause of creative responses to a construct within the organism as opposed to behavioral processes occurring over the course of time. The construct of "creativity" would not be of explanatory use in the general language if the controlling behavioral processes were salient and easily observable.

A second, and equally large limitation, is that due to the opaque nature of behavioral processes that produce creative responses, there is a tendency in both society and established research communities to reify creativity and treat it as an actual genetic or personality trait or cognitive process (Hennessey & Amabile, 2010). Such approaches are engrained in the language surrounding creativity and make a truly behavioral discussion of creativity difficult to have without referencing hypothetical constructs, accidentally or otherwise. In Skinner's final writing, he attributed the advancement of cognitive psychological explanations of behavioral phenomena to the similarity of their language and terminology to the vernacular (Skinner, 1990). A precise analysis of behavior will provide the distinct advantage of clarifying the reinforcement contingencies that are glossed over in cognitive analyses and everyday language. This analysis will, in time, need to overcome the clumsy and imprecise language of cognitive psychology in order to identify the causes of creative behavior. This language limitation is part of the reason why a behavioral analysis of creativity is of great interest, but it also creates an obstacle in the discussion and dissemination of such an analysis.

A third limitation is that interconnecting repertoires and contingency adduction can take a significant amount of time. The behavioral history of an organism required to build diverse and fluent skills and repertoires is considerably difficult, if not impossible, to completely control for, much less manipulate experimentally. Doubtless there are more limitations to a behavioral analysis of creativity, many of which are related to the language and general perception surrounding creativity.

The behavioral processes that produce novel responses of value are of interest in themselves, and it is clear that behavior analysis has advanced our understanding of "creativity" (Runco, 1993). It is at least equally clear that there is a significant amount of work that still needs to be done within the field to develop a robust behavior analysis of creative behavior. The ultimate goal of such an analysis ought to be the understanding of the relevant underlying processes and environment/behavior relations so that creative behavior can be engineered by manipulating environmental variables. If creative performance could be reliably and effectively trained or facilitated, then one could only imagine the advancements in science, business, health, education, and the arts.

In Epstein et al. (1984), the authors suspected and demonstrated that pigeons would be able to complete the complex task of directionally pushing a box underneath a suspended plastic banana, jumping onto the box and pecking the plastic banana without directly teaching such a chain of responses. The authors found that pigeons that were trained on each of three necessary component skills were able to complete the novel response chain. The current study uses the Epstein et al. model to investigate whether human participants will be able to create a magnetized compass with only training component skills. If Epstein et al.'s findings translate to human participants in this study, it would be expected that only participants trained on all necessary component skills will be able to "invent" a magnetized compass.

# Method

## Participants, Setting, and Recruitment

Nine potential participants completed the screening test and eight participants were selected for continuation in the study. The eight participants were randomly assigned to one of four groups, as described later. Potential participants were recruited from undergraduate courses at a large Midwestern university. The study took place in an academic research laboratory. There were multiple computers (unused in the current study), adjustable chairs, and tables separated by cubicle walls in this room. During relevant training and testing, the following items were randomly arranged on one of the tables: one sewing needle, one bar magnet with poles labeled "N" and "S," an 8-in wide dish filled with water, plastic forceps, a small LED flashlight, a 12-in long wooden ruler, and a 12-in piece of thread. Each potential participant was given a prestudy screening test composed of 20 questions. Responses on 5 of the 20 questions were used to select participants for continuation in the study. The five questions were designed to assess potential participants' knowledge on areas relevant to the study including magnetism, the Earth's magnetic properties, buoyancy, the use of a compass, and how a compass works. Only participants who answered all five screening questions incorrectly, demonstrating that they were naïve on the areas relevant to the study, were selected to continue in the study. All potential participants who answered any one of the five questions correctly were not selected for participation and were dismissed from the study. Only one of nine potential participants answered any of the five questions correctly and was not selected for further participation in the study. The remaining 15 questions were distractor questions and dealt with other topics related to science, such as how electricity travels through a wire and why the sky becomes red/orange at sunrise and sunset, and basic outdoor camping skills such as the use of strike-anywhere matches and tying a bowline knot. Responses on the 15 distractor questions were not considered in selecting participants for continuation in the study. These distractor questions were selected to prevent participants from attending to obvious thematic links that would encourage them to independently seek solutions to forthcoming tests outside of the experimental setting.

## Research Design

A case study design, similar to the one implemented by Epstein et al. (1984), was used in this study. Epstein et al. used 11 pigeons divided into five groups. Four pigeons were taught all component skills necessary to solve the problem. The other seven pigeons were divided across four conditions—three conditions with two pigeons and one condition with one pigeon—that involved training on a different combination of only some of the component skills. The current study had four conditions with two participants each.

### Independent and Dependent Variables

The independent variable was training on the combination of component skills necessary to build a magnetic compass that the participants were taught. There were two dependent variables: device success and session duration. Device success was assessed by whether or not the participants successfully built a magnetic compass that pointed North in the allotted 30-min time frame. For participants who successfully built a magnetic compass, the session duration variable was assessed as the time from the start of the testing session to the successful completion of the construction of the magnetic compass that pointed north.

### Groups

Participants in Group 4 were taught all three component skills necessary to build a magnetic compass including magnetism, floating a needle and magnetizing a needle, along with two distractor skills: how to thread a needle using the "pinch the thread" method and how a sundial works. Groups 1–3 were each taught a different combination of two of the three component skills. Group 1 was taught the same two distractor skills and magnetism and floating a needle as component skills. Group 2 was taught the two distractor skills and magnetism and magnetizing the needle as component skills. Group 3 was taught the two distractor skills and magnetizing the needle and floating the needle as component skills.

## Training Component and Distractor Skills

The process of constructing a magnetic compass was broken down into the following component skills: magnetizing a needle (an operation), floating a needle on water (an operation), and magnetism (a concept). A typical magnetic compass, such as one that could be bought at a sporting goods store, consists of a magnetic needle that floats in a liquid solution in an enclosed housing and is allowed to rotate freely around a fixed anchor point at the middle of the needle. The magnetized needle reliably orients itself in a north–south direction due to the needle's magnetic attraction to the Earth's magnetic north pole. The magnetic north end of a compass needle is magnetically attracted to the south pole of Earth's magnetic field, which lies close to Earth's geographic North Pole. Magnet fields have two poles, called a north pole and south pole. Magnetic north poles and south poles are attracted to each other. Also, magnetic north poles are repelled by magnetic north poles of other magnets and magnetic south poles are repelled by magnetic south poles of other magnets (Kuhn, 1996).

A magnetic compass can be constructed using the following common household objects: one metal sewing needle, one common bar magnet, plastic forceps, and a shallow dish filled with water. A standard metal sewing needle is able to be magnetized by stroking the pointed half against the south pole of a magnet. After the pointed end of the needle is magnetized, it can be made to float on water by carefully placing the needle on the surface tension of water using forceps. When left to float undisturbed for several seconds, the needle will rotate until it points in the direction of Earth's geographic North Pole.

As indicated earlier, it was critical to select distractor skills that would appear plausibly related to the targeted skills but would not be relevant to the final performance. The first distractor skill was demonstrating how a sundial works. This was selected as a distractor skill because it is a sufficiently complex concept, similar to the component skill concept of magnetism. The function of a sundial is also not useful or relevant to constructing or using a magnetic compass. Finally, this skill involves an aspect of rotational motion, similar to the needle rotating in a compass, in that the light source (flashlight) is moved in an arch-like motion over a ruler in order to cast a shadow on the table that appears to move in a semicircular motion.

The second distractor skill was threading a needle using a specific "pinch-the-thread" method. This was selected as a distractor skill because it is a sufficiently difficult fine motor skill, similar to balancing a needle on the surface tension of water. This skill is also not useful or relevant to constructing or using a magnetic compass. Finally, this skill involves the use of a needle in completing a fine motor skill, similar to floating a needle and magnetizing a needle.

Component and distractor skills were trained in a one-on-one setting using the following process. First, participants received verbal instruction about the skill from the researcher. For operations such as floating a needle using forceps or threading a needle, the researcher precisely specified the actions to be taken (e.g., "Then, moving very slowly and carefully, set the needle lengthwise onto the surface of the water. Make sure that when you release the needle from the forceps the needle is just touching the surface of the water. The needle won't float if it is released above or below the surface of the water." or "Next, pick up the needle with your dominant hand [the hand you write with] and hold the middle of the needle using your index finger and thumb. Make sure the eye of the needle is pointing up. Be careful not to poke yourself with the sharp end of the needle."). For concepts such as magnetism, the relevant features were highlighted (e.g., "You can see that the magnet has two poles; an N-pole and an S-pole" and "Even though the Earth is like a giant magnet, it is a rather weak magnet. It isn't strong enough to even align the N-pole ends of magnets that are lying on the table to the Earth's geographic North Pole. It is only strong enough to align N-pole ends of magnets towards the geographic North Pole when the magnets are able to rotate with very little friction; even less friction than they experience when lying on a table"). At the same time, the skill was modeled and explained by the researcher (e.g., holding the middle of the needle between the tips of the forceps; pointing to the poles of a magnet in relation to a representation of the globe). Then the participant practiced the skill (e.g., magnetizing a needle or labeling the magnetic poles of the Earth) and received positive and corrective feedback (e.g., "That's right! The Earth's magnetic S-pole is close to Earth's geographic North Pole" or "Think about it this way: opposites attract. The N-pole end of one magnet is attracted to the S-pole end of another magnet.") from the researcher. Finally, the researcher evaluated each skill for mastery using predetermined mastery criteria. Only after a participant demonstrated mastery for all of relevant component and distractor skills were they advanced to the testing session.

## Test Condition

Researchers collected participants' phones and watches prior to the test session because some of these devices have the technology to identify direction. These were returned to participants after the test session was complete. The testing session started with a researcher stating that the participant had 30 min to use the materials presented on the table to make a device that accurately and consistently identified geographic North. The word "compass" was not used by the researcher reading the script. Testing sessions lasted 30 min, or until the participant constructed a functional magnetic compass, whichever came first. The dependent variables measured were whether the participants were able to create a functional compass and, if a functional compass was constructed, the amount of time from the start of the test session until a functional compass was constructed.

## Analysis

### Data Collection

Data were collected by two researchers continuously observing the participants throughout each testing session. A digital timer displaying the minutes and seconds remaining in the session was visible to the researchers and participant during the test session. Once a participant was seated at the table, had the instructions read to them, and acknowledged that they were ready for the test session to begin, a researcher then started the digital time and the session began. The timer was stopped when the participant successfully completed the task, or when 30 min had elapsed, whichever was first. The researchers independently recorded the time displayed on the digital timer and recorded whether the participant created a device that successfully identified geographical North.

To assess whether a participant's device identified North, the researcher compared the participant-identified North with a store-bought magnetic compass that identified North. The participant's device was considered correct if the direction it identified as North was within 30 degrees of true North as identified with a store-bought magnetic compass.

### Interobserver Agreement

Interobserver agreement was calculated both on the session time recorded and on the scoring of the test session as successful or unsuccessful. Data points independently recorded by each observer were classified as in agreement or disagreement. The number of agreements were divided by the sum of agreements and disagreements. The resulting quotient was then multiplied by 100% to determine the interobserver agreement percentage. In this study, interobserver agreement was 100%.

### Data Reporting and Analysis

Data on the dependent variables are reported by individual participant and grouped as follows: the dependent variable of device success is reported as the percentage of participants in each group that successfully built a magnetic compass. Session duration is reported as the average time in minutes and seconds it took participants in each group to successfully build a magnetic compass.

# Results

## Group 1: No Magnetizing the Needle

Participants in Group 1 were trained on the component skills of floating the needle and understanding Earth's magnetism but were not trained on how to magnetize the needle. Neither of the participants in this group were able to successfully build a device that reliably pointed North before the end of the 30-min test session. Both participants floated the needle on the water at least once during the test session, but neither had attempted to properly magnetize the needle beforehand.

By the end of the 30-min test condition, one participant had constructed a device by leaning the ruler on the side of the water dish, tying the needle to the upper end of the ruler using the tread so that it dangled several inches from the surface of the table, and placing the bar magnet on the table a few inches away from the suspended needle such that the needle was being magnetically pulled towards the bar magnet but was unable to touch it due to being tied to the ruler. Although this device was visually interesting due to the needle being suspended at an angle, it did not reliably identify geographic North.

The other participant in Group 1 did not have any device constructed by the end of the 30-min test session. This participant had attempted several different combinations of the materials given throughout the session, including using variations of the sundial approach taught as a distractor skill in training.

## Group 2: No Floating the Needle

Participants in Group 2 were trained on the component skills of magnetizing the needle and Earth's magnetism but were not trained on how to float the needle on the surface tension of the water. Neither of the participants in Group 2 were able to build a device that successfully identified geographic North within the 30-min test condition. Neither participant attempted to float the needle on the surface tension of the water during the test condition. One participant dropped the needle to the bottom of the water dish for a brief moment during the test condition and noticed that the needle could be moved around the bottom of the dish by holding the magnet to the outside of the dish. This only lasted a matter of seconds before the participant removed the needle from the water dish and attempted to solve the task in other ways. Other than this brief episode, neither participant attempted to build a device that involved the water. Both participants, at times, used the edges or the outside of the water dish as a type of structural support in other unsuccessful attempts to build a device.

## Group 3: No Earth's Magnetism

Participants in Group 3 were trained on the component skills floating the needle and magnetizing the needle but were not trained on Earth's magnetism. Neither of the participants in this group successfully constructed a device that reliably identified geographic North. Both participants properly magnetized the needle and floated the magnetized needle on the surface tension of the water. At multiple points throughout the test session the needles in both devices were allowed to float undisturbed long enough to point toward geographic North, but neither participant gave any indication that they had solved the task or that they understood that the needle repeatedly rotated towards and pointed in the same direction. One participant spent over half of the session moving the bar magnet around the outside edge of the bowl, which caused the floating needle to move quickly across the surface tension of the water following the movement of the bar magnet. The other participant engaged in similar behavior for less than a minute and spent the majority of the session attempting to construct devices that did not include the needle floating on the surface tension of the water.

### Group 4: All

The two participants in Group 4 were trained on all three of the component skills including floating the needle, magnetizing the needle, and Earth's magnetism. One of the two participants in Group 4 successfully built a device that reliably identified North within 3:24. This participant did not immediately attempt to build a device, rather, the participant appeared to think for nearly a minute with one hand on their forehead while visually scanning over the materials. This participant then moved rapidly—in comparison to the other participants in the study—by magnetizing the needle and floating the needle on the surface tension of the water. Then the participant appeared to notice that the needle was drifting towards the magnet, which was laying on the table next to the water dish. The participant then picked up the magnet and placed it on the table on the opposite side of the bowl, but a few inches farther away from the bowl than it had been placed previously. This caused the needle to drift to the other side of the bowl towards the bar magnet. Within seconds, the participant picked up the bar magnet and held it several feet away from the bowl. When the magnet was removed, the needle oriented itself in a North/South direction, with the tip of the needle pointing North. The participant brought the bar magnet back towards the bowl, which caused the needle to rotate and drift towards the magnet. The participant then quickly moved the bar magnet several feet away from the bowl, which was followed by the needle rotating and pointing North within seconds. The participant repeated this a few times in rapid succession and then placed the bar magnet on the far end of the table, several feet away from the water dish and needle. Once the needle returned to pointing North, the participant notified the researchers that the device created reliably pointed North. The participant was able to correctly identify North as the direction the tip of the needle was pointing.

The other participant in Group 2 also constructed a similar device that would have been capable of reliably identifying North within the first few minutes of the test session but spent nearly the entire remainder of the 30-min session moving the bar magnet around the outside of the water dish causing the needle to rapidly drift across the surface of the water in the direction of the magnet. At no point did the participant hold or put down the bar magnet sufficiently far enough away from the water dish and needle so that the needle would not be affected by the magnetic field of the bar magnet. The participant also gave no indication during the test session that the constructed device was able to reliably identify North.

## Discussion

As previously discussed, creative problem solving has often been attributed to moments of "insight." Kohler (1925) stated as much in his observation of chimpanzees stacking and climbing boxes to obtain previously out-of-reach bananas. Epstein et al. (1984) was able to replicate the moment of "insight" with pigeons pushing and climbing on a box to peck a banana to obtain food. However, Epstein et al. did not attribute the successful pigeons' problem solving to "insight," as Kohler previously had. Rather, Epstein et al. credited the solution to fluent component skills and environmental conditions that resulted in the interconnection of repertoires. In the current study, the successful participant demonstrated a moment of "insight" at which the effective solution to the problem suddenly emerged. Rather than being a function of "insight," the innovative solution to building a device that reliably identifies North may likely be explained as the result of mastery of the three necessary component skills and being put in an environmental condition that results in the interconnection of those repertoires.

The arrangement of the current study was such that, if Epstein et al.'s (1984) explanation of creative problem solving was correct, only the two participants in Group 4 who were taught all three of the necessary component skills would be able to solve the problem, whereas the six participants in Groups 1–3 would be unsuccessful. The study found that one of two participants in Group 4 quickly solved the problem, whereas the other participant nearly solved the problem, and the remaining six participants did not solve the problem at all. These findings are consistent with Epstein et al.'s explanation of creative problem solving.

The current study contributes to the line of research in three substantial ways. First, it provides a proof-of-concept that Epstein et al.'s (1984) account of creative problem solving may translate to complex human problem solving in a laboratory setting. Second, it identifies a problem-solving task that can be used in future research. The problem-solving task used in the current study was sufficiently complex, involved a reasonable number of teachable component skills that potential participants are not likely to already know, produced a useful product that is known to the general public, and the product—at its original invention—was an example of Big "C" Creativity. Third, it lays out the framework for a future between-groups-design experiment that can investigate Epstein et al.'s theory behind creative problem solving by detailing the logic behind the number of groups and the component and distractor skills taught to each group.

## Limitations

The current study implemented a case study design with four groups of two participants each. This method was implemented to demonstrate proof-of-concept for Epstein et al.'s (1984) explanation of "insight" or creative problem solving. This case-study methodology does not allow for any causal relationships to be identified. The small number of participants also precludes a true correlational analysis to demonstrate a significant relationship between independent and dependent variables.

The concept of building a device that reliably identifies North was likely not entirely novel to the participants. Though it was not asked directly, it is assumed that most if not all of the participants have a general sense of what a compass is and that its function is to point North, or at least help identify direction. The screening questions the participants were asked ensured that none had a general understanding of how a compass works or its magnetic properties. Several participants did use the word "compass" at some point during the test condition either after the instructions were delivered or at the end of the test session when they described their device, though the researchers never used the word "compass" during the study. It is possible that that some of the participants attempted to use their recollection and understanding of a compass as a model in attempting to build a device that reliably identified North.

Participants were trained on, practiced, and demonstrated the component and distractor skills during one training session and were then required to demonstrate the skill correctly immediately before the test condition during a second session. For most skills—in particular floating the needle, threading the needle, and magnetizing the needle—this amount of training in the study seemed sufficient. For the more complex skills regarding Earth's magnetism and how a sundial works, additional training and practice may be beneficial. This is likely because these more complex skills represent concept learning (unlike the motor activities represented by the other skills) that would have benefited from extensive teaching and testing using multiple examples and nonexamples (Tiemann & Markle, 1990). Three of the eight participants required additional refresher training on Earth's magnetism during the second session immediately before the test. Two participants required refresher training on how a sundial works. No more than one participant required refresher training on any of the other skills.

## Recommendations for Future Research

In order to address the limitations identified above, future studies using this task should use a true between-groups experimental design in order to determine if there are significant differences between the performances of each of the four groups. The current study identified a viable research structure and experimental task but did not use a sufficient number of participants to conduct significance testing to identify if there were any significant differences between the groups. In addition, future studies may benefit from adding two sessions for participants who were trained on all but one of the component skills and did not successfully complete the task during the 30-min test condition. The first additional session would involve training the missing component skill that the participant was not originally taught during the first training session. The second additional session would be another test session with the same task and instructions as the first test condition. This would allow for a type of multiple baseline design which could provide an added level of within-subjects analysis in addition to the between-groups analysis.

Epstein et al. (1984) emphasized the importance of a moment-by-moment account of the problem-solving process to provide a behavioral explanation for the phenomenon of insight. The current study provided anecdotal descriptions of the general problem-solving process but did not provide a true moment-by-moment account. Future studies could video record the test sessions in order to capture a moment-by-moment account. This would provide three benefits to the research. First, a more descriptive and accurate moment-by-moment account can be provided by analyzing and comparing the video of recorded test sessions without the practical limitations of real-time observation. Second, the moment of "insight" in problem-solving process can be captured and analyzed. This would allow for more precise identification of the conditions and processes resulting in "insight." Also, the recording of these moments of "insight" that are recognizable to lay observers and the general public could provide strong social validity to the results of the study. This would be in line with Epstein et al.'s (1984) study in which the problem solving of performance of pigeons was recorded and made a case for the face validity of the research. Third, video recording would allow for additional methodological integrity during the test sessions and provide greater scheduling flexibility as only one researcher would need to be present during the test condition while a second researcher could record interobserver agreement data from the video recordings at a later time. Fourth, a protocol analysis with a talk-aloud component could be used in addition to video recording to capture information from the participants' perspective as they solve the problem in real time (Austin & Delaney, 1998). This may lead to a more thorough and accurate moment-by-moment account of the problem-solving process.

## Conclusion

The ultimate goal of a behavior analysis of "creativity" is to understand the processes and relationships between environment and behavior that produce creativity to bring about the possibility of creating creativity by arranging environmental variables. Epstein et al. (1984) established a framework for the research to achieve this goal with complex problem solving in pigeons. Until now there have been no studies that have developed a similarly complex, socially significant, Big "C" creative problem-solving task to be used in research with adult human subjects. This study also suggests the initial translatability of Epstein et al.'s analysis and explanation of the underlying behavioral processes from animal research to adult human subjects. In conclusion, a comprehensive analysis of creativity could lead to the ability of creating creativity, which would certainly be a pretty creative creation created by the field of behavior analysis.

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**Data Availability** Data supporting the findings and information regarding materials used are available from the corresponding author upon reasonable request.

## Declarations

**Conflict of Interest** The authors declare that they have no conflicts of interest.

**Ethical Approval** All procedures performed in studies involving human participants were in

accordance with the ethical standards of the institutional and/or national research committee and

with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

**Informed Consent** Informed consent was obtained from all individual participants included in the study.

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