Need-solution pair recognition driven by object oriented solution-finding

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Abstract

It is generally assumed that in order to find a solution, one must begin the process by first identifying a problem, followed by attempts to solve it. This notion, however, was challenged by von Hippel and von Krogh (2016); rather than starting the process with problem formulation, people may also find solutions by having insights regarding both a previously unidentified need *and* a responsive solution - a "need-solution pair." In this paper, we provide empirical evidence for need-solution pair recognition, and also identify the cognitive mechanisms that may underlie this form of solution-finding. We posit that need-solution pairs emerge from a robust recognition system that relies on action-oriented, function-based reasoning about objects.

To test this hypothesis, we conducted an experiment in which we manipulated functional object reasoning by (1) adjusting object familiarity and (2) adjusting the level of instructions to actively solve problems. In the context of our experiment, solutions by need-solution pair recognition occurred just as often as need-first solutions, with need-solution pair recognition being best supported when constraints on functional object understanding were reduced. Specifically, identification of need-solution pairs was enhanced most in environments with unfamiliar objects, where participants were *not* directed to solve specific problems. These results are consistent with research in cognitive neuroscience that explicates the importance of functional understanding of objects in recognition. We extend this research by showing that functional object understanding can result in solution-finding under the right circumstances. We conclude with a discussion of implications of our findings for further research and improved practice.

Keywords: Need-Solution pairs; Insight; Object understanding; Affordances; Solution finding; Problem-solving; Innovation; Creativity; Knowledge production; Information transfer costs; Managerial and organizational cognition; Organization and management theory; Information transfer costs

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1. Introduction and overview

Problem-solving is typically conceived of as a two-step sequence: first identify a problem, followed by a search for possible solutions (e.g., Newell & Simon, 1972; Sternberg & Frensch, 2014). Recently, however, von Hippel and von Krogh (2016) proposed a second and quite different way in which problems can be solved. Rather than start with a problem and then seek possible solutions, people can also solve problems by having an insight comprising both a novel need *and* a responsive solution – a "need-solution pair." This proposal is directly at odds with traditional problem-solving research which, as was just noted, generally assumes that in order to find a solution, one must begin the process with the identification of a problem followed by attempts to solve it either consciously (e.g., De Bono, 2006; Gick, 1986) or unconsciously ((e.g., Dorfman, Shames, & Kihlstrom, 1996) – thus, "problem-solving." For example, in research on problems that are difficult and opaque, it is assumed that one starts with a problem that is then analyzed, with putative solutions being considered, tested, rejected and revised over and over again (e.g., Duncker, 1945; Knoblich, Ohlsson, Haider, & Rhenius, 1999; Kounios & Beeman, 2009; Maier, 1930).

In the present paper, we experimentally examine a possible cognitive mechanism by which need-solution pairs can arise. In brief overview, we find evidence to suggest that need-solution pairs arise as an insight in response to the perceptual apprehension of an object's function, wherein the perceived function of the object (or attribute of the object) is understood as a solution to a previously unidentified problem. (By 'object' we mean any entity that has a function. This includes physical objects, but also can include processes, procedures, algorithms, tastes, sounds, feelings, textures, ideas, etc.) Our proposal is consistent with research in the area cognitive neuroscience that has demonstrated the import of situated, action-oriented, function-based reasoning about objects in achieving robust object recognition (Goodale, 2014; Milner, 2017; Milner & Goodale, 2006, 2008; J. Norman, 2002; Young, 2006).

Prior research on the way people understand objects has demonstrated that recognition of an object is highly intertwined with understanding its perceived function (Gibson, 1977, 1979; D. A. Norman, 1990). For example, a pencil holder can be recognized as a cup if it can hold liquid. In a similar vein, that same pencil holder can be recognized as a vase in which to place fresh cut flowers. Under this view, the recognition of any given object is largely afforded by its perceived

function. This may be especially true for novel objects, where the form or features of the novel object yield multiple hypothesized uses or functions (consciously or unconsciously) through which the object can be understood. While the reliance of object recognition on functional understanding has been recognized (e.g., Noë, 2004; J. Norman, 2002), it remains an open question whether functional object understanding can sometimes yield solutions independent of problem-formulation.

In order to assess the nature of need-solution pair insights and its relation to functional object understanding, we conducted an experiment in which we manipulated object novelty (within subjects) as well as the degree to which participants were encouraged to actively problem-solve on specified topics (between subjects). Our goal was to create more vs. less favorable conditions for the emergence of need-solution pairs. As the functional understanding of familiar objects may be constrained to functions associated with their canonical usages (Chrysikou, 2006; Duncker, 1945), we anticipated a decrease in the occurrence of need-solution pair recognition when interacting with familiar objects compared to novel objects. To test this, participants were exposed to two sets of objects that differed in perceived visual novelty (low, followed by high) in a block design over the course of the experiment. Our data support the notion that environments of high visual novelty better support need-solution pair recognition.

Beyond object novelty, we additionally hypothesized that instructions by the experimenter to solve a specific problem would reduce the occurrence of need-solution pair insights. By our logic, an actively considered problem should work to constrain the functional understanding of objects to those functions that potentially satisfy the needs of the problem posed by the experimenter (c.f., Colzato, Ozturk, & Hommel, 2012), and as such, limit need-solution pair occurrence. To test this, we randomly assigned participants to one of three conditions that varied in the level of overt instruction to solve a problem, while they were placed in an object-rich environment. If an actively held problem does constrain functional object understanding and need-solution pair recognition arises from such understanding, we should find that the occurrence of need-solution pair recognition should decrease as overt instruction to solve a specific problem is increased. In our experiment, we did indeed find that the occurrence of need-solution pair identification decreased the more a participant was encouraged to engage in specific problem solving.

The notion that a problem can constrain the breadth of functional object understanding hints at an important feature of object-based solution spaces: As they are not dependent on problems, such spaces may contain solution paths to problems not yet known or considered. Indeed, it is in these cases we argue that need-solution pair identification arises. Again, our results and this reasoning are consistent with research in the area of cognitive neuroscience (Milner, 2017; Milner & Goodale, 2006, 2008; J. Norman, 2002; Young, 2006) that has demonstrated that robust recognition of objects relies on situated, action-oriented, function-based reasoning about objects. In a discussion we extend this finding, and argue that solution finding very generally may be an emergent property of how we reason about and perceive objects.

In the sections that follow, we will begin by reviewing theoretic contributions from cognitive psychology, neuroscience and philosophy to understand the import of perceived function in object understanding. We then shift to consider how need-solution pair insights may be a natural product of the functional understanding of objects. In the subsequent two sections we then outline the logic, design and methodology of our research and report our results. The final section concludes with a discussion of both the theoretical and practical implications of our findings.

2. Theoretical Framework

2.1 Understanding the Import of Perceived Function in Object Understanding

In 1977, Gibson coined the term of "affordances" to refer to the set of potential uses or functions a given object or set of objects may possess. For Gibson, the affordances of a given object represent an invariant mapping from the features and form of a given object to its meaning, suggesting that affordances themselves are the object of perception (Gibson, 1977, 1979). Some have taken Gibson's view to suggest that the representation (or meaning) of any given object is made available via the potentiation of all its possible uses (Chemero & Anthony, 2009). The primacy of affordance perception stems from the general observation that individuals seem to be able to perceive the function of objects just as readily as their simple physical features. Indeed, Gibson proposed that the direct detection of possible affordances is achieved at an evolutionary timescale, with selection for the detection of affordances not occurring within the lifetime of any one observer, but across the history of the species. From this perspective, the

evolutionary purpose of our visual system is to perceive affordances. While Gibson's theory of affordances has made powerful claims regarding the import of functional object understanding in shaping and constraining object recognition, it left little insight in explaining how the detection and perception for affordances may be also contextually and culturally determined via an observer's past experience. Enactive and embodied theories of perception however, have extended Gibson's original term of affordance to acknowledge the dynamic interdependence that exists between an observer's intentions and the affordances of the environment (Chemero & Anthony, 2009; Noë, 2004; Thompson, 2007; Varela, Thompson, & Rosch, 1993).

Enactive or embodied theories of perception have posited that affordances are perceived through the sensorimotor systems in the brain (Barsalou, 1999; Chemero & Anthony, 2009; Glenberg, 1997). Under such a view, when one looks at an object, one recognizes it via its potential uses or functions by internal simulations of potential motor actions afforded by the object. Such a view is supported by converging evidence across a wide range of studies showing that the recognition of an object entails the contemporaneous activation of sensorimotor areas that capture the potential uses and functions of the given object along with other representations such as the given object's visual image and sound (Allport, 1987; Anderson, Yamagishi, & Karavia, 2002; Damasio, 1989; Lissauer & Jackson, 1988; Rogers et al., 2004; Saffran & Schwartz, 1994; Simmons & Barsalou, 2003; Warrington & Shallice, 1984). While co-activation of perceptual and sensorimotor areas suggests the importance of functional understanding in the recognition of objects via simulated action, neuropsychological evidence from humans and macaque monkeys indicates that object recognition may be best described by two neural pathways, with interactions between the pathways capturing the dynamic relationship that exists between knowledge from prior experiences (specified here as learned affordances) and action-mediated recognition from physical features (specified here as physical affordances) (Milner, 2017; Milner & Goodale, 2006, 2008; J. Norman, 2002; Young, 2006).

Strong evidence for the distinction between physical and learned affordances comes from case studies of patients with semantic deficits in object perception as a result of damage to the ventral system that projects from visual cortex to the inferior temporal cortex. While these patients are able to correctly speculate on possible uses or functions of common objects based on specific visual features (due to an intact dorsal processing system that projects from primary visual cortex to superior parietal cortex), they are unable to demonstrate a familiar object's

conventional use or function (Young, 2006). This evidence is consistent with the notion that ventral stream processing allows for past experiences, current goals, and expectations to be brought to bear for object recognition, while dorsal stream processing appears to be much less influenced by such information, and as a consequence is more stimulus-driven. For this reason the balance between ventral and dorsal processing is critical, as the two systems appear to work in tandem to balance perception from being overly driven by either learned affordances (via the ventral system) or physical affordances (via the dorsal system) (c.f., Fox et al., 2005). Arguably, this suggests that object recognition is determined by the interplay between (1) recognizing physical affordances and (2) the constraint or augmentation of that set from learned affordances by current circumstance and past experiences.

2.2 Beyond Recognition: Affordances as Solution-Spaces

While we have argued that object understanding is determined by both learned and physical affordances, this is not to say that affordance understanding only subserves object understanding. Affordances by their very definition (whether learned or physical) represent the full set of action possibilities available to an individual (Milner, 2017; Milner & Goodale, 2006, 2008; J. Norman, 2002). Given that these action possibilities can be thought of as potential solution paths available to an individual, affordance understanding may have large implications for solution-finding. This notion is perhaps best articulated in research in autonomous robotics, which has capitalized on affordance-based processing as a possible way to simulate human-like problem-solving behavior. This work has demonstrated that by offering a computing architecture that supports action-object mappings, a robot is able to develop an understanding for how actions generally relate to the physical properties of objects (physical affordances) and over time how such relationships relate to circumstance or desired goals (learned affordances). Notably, the implementation of affordance understanding has been demonstrated to lead to seemingly complex behaviors, such as: (1) the ability to make predictions about how a given action will affect an object; (2) the ability to infer the intent of an observed action; and (3) the ability to achieve goals (or solve problems) in novel environments with novel objects (Gonçalves, Abrantes, Saponaro, Jamone, & Bernardino, n.d.; Lopes, Melo, & Montesano, 2007; Saponaro, Jamone, Bernardino, & Gonçalves, 2014). This indicates that complex behaviors such as problem-solving or solution-finding may be best thought of as emergent properties of situated,

action-oriented object understanding. Accordingly, the examination the affordance landscape as a solution space that is independent of problem-formulation offers the powerful observation that situated action-object understanding provides powerful machinery to achieve complex behaviors that go far beyond granting object understanding.

2.2.1. Overt Instruction to Problem-Solve and its Influence on Affordance Perception

The notion that solutions may also be populated via the perceptual apprehension of an object's function rather than solely through an actively considered problem, hints at a potentially important feature of object-based solution spaces: as object-oriented solution spaces are, not by definition, derived solely from problems, it stands to reason that such spaces may hold solutions to problems-not-yet-considered. Indeed, it is in these cases we argue that need-solution pair recognition arises.

To be clear, the notion that individuals perceive solutions through their interactions with objects independent of problems does not mean that an actively considered problem will not influence affordance processing. As discussed in section 1, we hold that an actively considered problem will necessarily influence one's current goals, which will in turn leverage past experiences and influence expectations (e.g., Adamson, 1952; Chrysikou, 2006; Chrysikou & Weisberg, 2005), all in an effort to collectively reorganize and constrain the affordance landscape to identify solution paths that satisfy the needs of the considered problem (see Getzel, 1975). This has critical implications for need-solution pair recognition, as problem-oriented solution-finding necessarily directs attention away from solution paths available to the individual for needs *not* associated with the actively considered problem. Given our view on how actively held problems necessarily constrain affordance understanding we propose the following:

Hypothesis 1a (H1a). *As active engagement in problem-oriented solution finding is decreased, need-solution pair identification should increase.*

Hypothesis 1b (H1b). *As active engagement in problem-oriented solution finding is decreased, traditional problem-first solutions should decrease.*

2.2.2. Object Familiarity and its Influence on Affordance Perception

As we have previously discussed, the affordance landscape for a given perceiver is defined through an interplay between observable affordances and those learned via past experience. This interplay becomes clear when considering how affordance processing for a given object may change with experience. Previous research has shown that once a particular usage for an object is reinforced, participants are unable to subsequently use the object in a novel way for the purpose of problem-solving (Adamson, 1952; Birch & Rabinowitz, 1951; Duncker, 1945). For example, participants will fail to see that they can use a hammer as a counter weight to make a pendulum to solve a problem, as the affordance they ascribed to a hammer is limited to its canonical usage: to drive nails. This notion, that an individual is unlikely to deviate from the previously learned affordance of an object, has been referred to as "functional fixedness" (Chrysikou & Weisberg, 2005; Duncker, 1945). With regard to affordance understanding, functional fixedness can be thought of as a bias that naturally directs attention away from ad hoc functions that may be available to the individual. Findings related to functional fixedness are quite robust and have been broadened over time beyond physical objects to show the effect is very general. More specifically, it has been shown that participants familiar with a complicated problem-solving strategy are unlikely to devise a simpler one even when appropriate (Allen & Marquis, 1964; Luchins, 1942). Given our view, that constraints to the affordance landscape will hinder need-solution pair recognition, we propose the following:

Hypothesis 2a (H2a). *Interactions with visually novel objects (as opposed to visually familiar objects) will result in an increase in the production of novel solutions via need-solution pair recognition*.

Hypothesis 2b (H2b). Objects that are judged to be more *visually novel (as opposed to visually familiar) will trigger more novel solutions via need-solution pair recognition*.

2.2.3 Creativity and Affordance Perception

There is a growing consensus among cognitive psychologists that a key cognitive process important to creativity is analogical reasoning (Barnett & Ceci, 2002; Bowdle & Gentner, 2005;

Green, Fugelsang, Kraemer, & Dunbar, 2008; Holyoak & Thagard, 1995; Mayer, 1999; Sternberg, 1977). Broadly, analogical reasoning is the process by which individuals make sense of a novel situation or object by comparing it to more familiar situations or objects. In terms of affordance processing, analogical reasoning may be an important mechanism by which perceivers are able to transfer learned affordances from past objects to new objects (Chaigneau, Barsalou, & Zamani, 2009). Previous research on analogical reasoning as has demonstrated that analogies that bridge large semantic distances are generally perceived as more creative than those that bridge small distances (Dunbar & Blanchette, 2001; Holyoak & Thagard, 1995; Sternberg, 1997). More specifically, semantically distant analogies are perceived as more creative than semantically close analogies, as distant analogies are generally found to be less apparent than semantically close analogies (Holyoak & Thagard, 1995). Further, as distant analogies allow for novel comparisons that can reveal other aspects not yet considered, semantically distant analogies are also thought to be more valuable than semantically close analogies (Dunbar & Blanchette, 2001; Holyoak & Thagard, 1995; Sternberg, 1997). When compared to familiar objects, which are often understood through their canonical usage due to functional fixedness that can inhibit analogical reasoning (Christensen & Schunn, 2007), novel objects can be viewed as offering perceivers comparatively more opportunities to demonstrate generativity and creativity. In the context of affordance processing as an opportunity for solution-finding, we therefore posit that interactions with visually novel objects will not only result in an increase in the production of novel solutions via need-solution pair recognition, but that such interactions will provide better opportunities for creativity and generativity. As such, we propose the following:

Hypothesis 3 (H3). *Solutions recognized as an output of need-solution pair recognition will have higher perceived value and creativity than solutions found via traditional problem solving*.

3. Materials and Methods

3.1 Participants

Seventy-four participants were recruited from the local community surrounding Technische Universität Darmstadt (63.5% = male, 36.5% = female; M = 25 years, range: 13 years to 59 years; 60 undergraduate students, 14 non-students). Informed written consent for all participants was obtained prior to the experiment in accordance with the guidelines established by the German Ethics Council applied by the ethics council of Technische Universität Darmstadt. All participants received financial remuneration of 10€ for completing the study, and additionally had the chance to win an Amazon voucher of 100€. Given the expected effect sizes and methods used to test our hypotheses, a total of 74 participants was considered an appropriate sample size (G*Power 3.1.92 software, see Faul, Erdfelder, Lang, & Buchner, 2007).

3.2 Experimental Setting

The experimental procedure was carried out in a research lab at Technische Universität Darmstadt. As we were interested in understanding the mechanisms that underlie need-solution pair recognition, we constructed a room at Technische Universität Darmstadt to resemble an "Airbnb" environment intended to be rented to guests for overnight stays (See Figure 1, Panel A). This environment allowed us to surround participants with familiar and everyday objects within a contextual background familiar to participants. During a pre-session briefing, all participants received a general description of Airbnb and how it works to make them aware of the environment in which they would be placed and to provide a similar contextual background across all participants (Aguinis & Bradley, 2014). In order to be consistent with an Airbnb environment, the room was stocked with furnishings and objects likely to be familiar to participants and appropriate for overnight stays – e.g., a table and chair, a bed, a bookshelf with books, and some small plants near a window. It also contained a closed opaque cabinet filled with visually novel objects (See Figure 1, Panel B), which participants were only invited to open at the midpoint of their individual experimental session. A separate room, with no view of the experimental setting, was used for pre- and post-session interviews with research participants.

Figure 1: Panel A shows the experimental setting in which participants were placed. Panel B shows the object cabinet that was filled with visually novel objects.

3.3 Experimental Procedure and Design

On arrival, participants were randomly assigned to one of three conditions that differed only in terms of the level of overt instruction to problem-solve. In the first condition, participants were invited to simply enter and explore the room without any explicit instruction to problem solve (N = 25), here after referred to as the "NoPS" condition. In the second condition, however participants were invited to develop an idea for something that could be useful to them or others while they explored the room. As such, the second condition represented an invitation to explicitly problem solve at a broad level when exploring the room (N = 26), here after referred to as the "BroadPS" condition. In the third group, participants were asked to think of needs and problems specific to people in an Airbnb setting and create useful solutions to those needs while exploring the room. Compared to the BroadPS condition, the third condition (here after referred to as the "SpecificPS" condition) represented an invitation to explicitly problem-solve in a much more specific, and narrow way (N = 23). To ensure each participant understood the instructions associated with their condition, participants were asked to write down what they understood the instructions to be. In case of any issues or differences, we corrected their understanding, and asked them to again provide a written summary of the instructions to double check that they were properly understood.

Before entering the Airbnb room participants were also asked to wear a wireless video and eye-tracking apparatus that looked like a pair of eyeglasses. As was explained to participants, this apparatus would continuously transmit to a remote recording device located in the interview room. It would enable the experimenters to record a continuous visual image of

where participants were located in the Airbnb room at any moment, and also exactly what they were looking at. (The specific apparatus used was the wireless SMI Eye Tracking Glass 2.)

After instructions were made clear, each participant was invited to enter the Airbnb room that contained visually familiar objects. Participants were free to move around and handle objects or shift their locations. At the end of each session, the experimenters returned all objects in the room to their original positions, and re-closed the cabinet filled with visually novel stimuli. For all sessions, the experimental room was kept free of external sounds, and room lighting and room temperature were maintained at normal residential levels. After the first 5 minutes of browsing the room filled with familiar objects, participants were then given a key, and asked to open the (opaque) door to the cabinet containing the visually novel objects. The cabinet contained an assortment of visually novel, domestic objects (See Figure 1B). For example, a foot-long hollow tube 1 inch in diameter had a head shaped like a bear and many small indentations for feet. While this object was intended by the producer to be used to make ice cubes (by partially filling it with water and putting it into a freezer "feet down" so that many small ice cubes would then form in the indentations for the bear's feet) such a use was not obvious to most participants based on visual inspection alone, as the object is visually distinct from most other ice cube trays. Participants were then invited to stay in this setting containing the visually novel objects for five more minutes, after which they were asked to leave the Airbnb setting and return to the interview room for a post-interview and debriefing. In addition, as a source of contextual and explanatory data, information on participants' personality traits and their moods were also collected. Data related to participants' experiences in all three experimental conditions were collected both immediately prior to and immediately following participants' 10-minute sessions in the experimental setting.

3.4 Data collection and analysis methods

Recall that the primary purpose of this experiment was to examine how visual object novelty and explicit instruction to solve a problem affects the occurrence of (1) need-solution pair (NSP) solution finding (occasions where both need and solution were recognized by the participant simultaneously) and (2) traditional "need first" (NF) solution-finding. To answer these questions we utilized a 2-by-3 effect design, containing both a between-subject manipulation (Task Instructions: NoPS, BroadPS, and NarrowPS) and a within-subject

experimental manipulation (Visual Novelty: Low and High). Given our interest in directly comparing the number of solutions by NSP (occasions where both an unknown need and solution were recognized by the participant simultaneously) to the number of need-first (NF) problem solutions generated (occasions where a solution was found for a previously known problem) for each experimental condition, these measures were treated in tandem as a repeated dependent measure. Lastly, we verified the effectiveness of our within-subject manipulation by asking each participant during debriefing to assess the unfamiliarity, innovativeness, complexity, and their interest using a 5-point Likert scale, of the Airbnb setting both before and after the cabinet was opened. As can be seen in Table 1, the desired effect was achieved.

Table 1: T-test for mean differences in perception of the setting before and after our novelty-enhancement manipulation

Perception of the setting as…[1]	*Low Novelty Setting (I)*	*High Novelty Setting (J)*	*Mean Difference (I-J)*	*Sig.*
Interesting	2.25	3.18	-.93***	.000
Innovative	2.00	3.01	-1.01***	.000
Complex	1.10	2.30	-1.20***	.000
Unfamiliar	2.47	3.23	-.76***	.000

[1] *Measured on a 5-point Likert scale: 1 = not at all, 5 = extremely*
**** Mean difference is statistically significant at p < .001*
N=74.

3.4.1 Video and eye-tracking information: Data on NSP and NF occurrences were collected from participants after each experimental session using the video of each participant's session, including eye-tracking information (shown as a moving dot within the video image). This footage was then played on a screen for the participant and interviewer to look at jointly. The participant was then asked to use the footage available to recall the thoughts they had while they were in the Airbnb room. Using first-person perspective videotapes to trigger participants' recall of mental events is a common approach in psychology, marketing and creativity research (Belk & Kozinets, 2005; Glăveanu & Lahlou, 2012; Lahlou, Le Bellu, & Boesen-Mariani, 2015; Rosenthal & Capper, 2006). It is thought that participants are better able to recall their thoughts while watching a replay of the events.

3.4.2 Coding instances of problem solving: As previously indicated, all NSP and NF occurrences were noted during the video review process. In order to correctly classify solutions as NSPs or NF solutions, all solutions discussed by participants were subject to a series of questions. More specifically, when participants indicated in their narrative that they had been thinking about a need and/or a solution, the experimenter asked them: (1) whether their awareness of the need preceded and triggered their search for a solution (an instance of the traditional NF problem-solving pattern) or; (2a) whether the solution occurred spontaneously as an insight along with the need it satisfied. If they said that the solution occurred spontaneously to them, they were additionally asked (2b) whether both the need and the solution in question were previously unknown to them before their insight. Only if they also answered yes to this second question, did the experimenter then code that occurrence as an instance of NSP discovery. Via this procedure, we were able to gather occurrence data for NSP recognition and NF solutions.

3.4.3. Coding novelty, creativity, and general value of solutions: As part of the debriefing process described above, we asked the participants to *describe* each need and related solution that had come to their minds during their time in the experimental setting, and wrote down what they said. We then showed the participants what we had written, and corrected any misunderstandings that they pointed out (Glăveanu & Lahlou, 2012). At the end of the interview, we asked participants to rank their discoveries, starting with the "most important" one.

We later asked four graduate student lab assistants to serve as third-party raters and independently assess the (1) novelty, (2) creativity, and (3) general value of each discovery based upon the short description of each that had been collected as described above (N = 314). The use of independent coders to assess individual outcomes such as creativity or novelty of ideas is widely accepted and established in management research and is assumed to reduce common method bias (Baer, Smith, & Allen, 2004; Barsade, 2002; Ford & Gioia, 2000; Perry-Smith & Shalley, 2014). As recommended by extant research, we adapted a two-way rating approach by asking each rater to provide a score for each measure and each idea (Baer et al. 2004; Saal et al. 1980). Initially, raters jointly reached a consensus on what each brief description meant – what the product to be rated actually was and what its intended function was. Next, they performed the

rating task independently, with no consultation about the ratings throughout the whole rating process (Amabile, 1983).

Novelty was measured using a self-developed three-item construct, based on the novelty dimensions of Im and Workman's (2004) scale adapted by Stock et al. (2014). The measure was designed to cover multiple dimensions of novelty using the following items: (1) "The solution is novel", (2) "The solution is unique compared to other solutions on the market", and (3) "The solution is really out of the ordinary". Raters scored each of the items on a five-point scale ranging from (1) strongly disagree to (5) strongly agree. Overall, the ICC scores for each item show good inter-coder reliability (ICC scores were 0.78, 0.77, and 0.77 respectively). Accordingly, we averaged the scores. A Cronbach's alpha of 0.89 showed good overall construct reliability of the novelty scale, allowing us to use average construct scores in our further analyses.

Creativity was measured as a subjective degree on a 5-point Likert scale inspired by Amabile (1983). Accordingly, each rater reported the degree to which by his or her own subjective definition of creativity, the solution was (1) very uncreative – (5) very creative (ICC = .80). Average values on the item level were computed.

General value was assessed using a single item measure put forth by de Jong and colleagues (2015). Specifically, independent coders assessed the degree to which the solution would be valuable to other people (ICC = .61). Ratings were coded on a 5-point scale with respective anchors ranging from "no potential" to "great potential". Again, average values on the item level were computed. In addition to post-session data collection on NSP and NF occurrences, questionnaire data on other matters were collected from all participants prior to the start of their session in the Airbnb room, and also immediately after their session.

The self-rated personality trait for *Openness to experience* was assessed using a 4 item measure developed by Donnellan and colleagues (2006). This measure includes questions such as, "I have a vivid imagination", or when reverse coded, "I have difficulty in understanding abstract ideas". The construct was assessed on a 5-point Likert scale (1=not at all, 5=very much). This was done so as to capture the participants' openness to experience and mood state.

Mood states were assessed, in response to the prompt, "To what extent do you feel this way right now, that is, at the present moment/how did you feel at the end of the experiment?" on a 5-point Likert-type scale (1 = "not at all," to 5 = "very much"). The included adjectives were based on single measures of the PANAS (Positive and Negative Affect Schedule; Watson, Clark, & Tellegen, 1988) and included adjectives, such as afraid, inspired, or energetic.

3.4.4. Coding visual novelty associated with each object that triggered either a Need-solution pair or Need-first solution:

For each solution reported, we asked the participants if there was an object or groups of objects that lead to the solution (either NSP or NF). In 90% of the instances, our participants were able to identify an interaction with an object in the setting that led to their solution (either NSP or NF). We later asked four graduate-level lab assistants to serve as third-party raters and independently assess object novelty for each of the identified trigger objects. While we were only interested in visual novelty ratings for the trigger objects, raters asked to rank: (1) how novel the trigger item looked as well as; (2) how novel the trigger item was in terms of its intended function. Each assessment was done using a 6-point Likert scale (1 = Highly Not Novel, 6 = Highly Novel). While these two items are likely related, this was done so as to make sure that raters knew to separate visual novelty from novelty associated with the object's possible function. The four rater's assessment of visual object novelty (Cronbach's alpha 0.80) and assessment of novelty for each object's intended use (Cronbach's alpha 0.80) both showed high agreement among the raters. While the two novelty assessments (visual appearance and usage) were significantly correlated ($r = 0.253$, $p = 0.04$), the percent of total variance explained by the relationship was less than 7%. Per H2b, the measure of visual novelty for each trigger object was obtained so as to assess if high visual novelty positively predicts how often an object serves as a trigger for a NSP.

3.4.5 *Coding the relationship between solution content (either NSP or NF) and areas of special interest and knowledge help by participants.*

To understand how the content of found solutions (either NSP or NF) relates to special interests and knowledge held by an individual, we additionally collected data from all of the participants in our experiment regarding their personal interest in each of 10 general interest domains: Art, Design, Architecture; Education and Upbringing; Medical and Health; Communication and Languages; Animals and Nature; Technology; Food and Drinks; Sports;

Travel; and DIY activities (Brickenkamp, 1990). To evaluate the relationship between the personal interests of each participant and the application area of their innovations, for each participant we: (1) scored the relatedness of each discovery (N = 314) to each of the 10 interest domains ranging from 1 (not related) to 5 (very related). This will allow us to examine if there is a relationship between personal interest domains score of each participant and the relatedness of that participant's discoveries to those domains.

4. Results

In our experiment, we documented many instances of NSP recognition and NF solutions among our participants. The occurrence of solutions per participant (NSPs + NF solutions) during their 10 minute sessions in the experimental setting ranged between 1 and 12 solutions per participant with a mean of 4.24 and a standard deviation of 2.34. As prior literature would suggest (Stock, von Hippel, & Gillert, 2016), the total number of solutions generated by individual participants was significantly correlated with the degree to which each participant displayed the personality trait, openness to experience ($r=0.268$, $p=0.021$).

4.1 Effect of Novelty and Instruction Type on the occurrence of NSP and NF solutions.

In order to assess the effects of both the explicit instruction to problem-solve (See Hypothesis H1a/H1b) and object novelty (See Hypothesis H2a) on solution occurrence, a 2 (Object Novelty: Low vs. High – within subjects) x 3 (Instruction type: NoPS, BroadPS, SpecificPS – between subjects) x 2 (Solution Type: NSP count vs. NF solution count – within subjects) mixed-effect general linear model was used. Of the three main effects in the model, only the main effect of Object Novelty ($F_{(1,71)} = 120.802$; $p<0.0001$) was found to be significant. This significant main effect indicates that independent of solution type, more solutions were found when participants were exposed to visually novel objects (1.67 solutions) than when exposed to visually familiar objects (0.46 solutions) (See Figure 2). This is consistent with our view that interactions with familiar objects may naturally obscure ad hoc affordances through functional fixedness (Duncker, 1945), and as such, limit solution finding, by constraining the solution space.

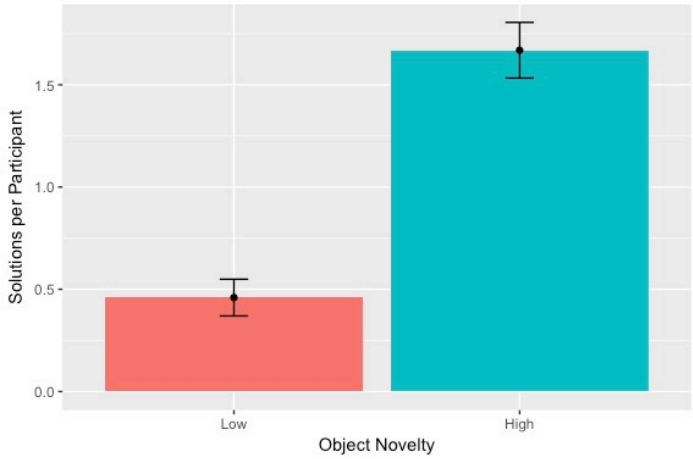

Figure 2: Interactions with visually novel objects yields more solutions (independent of solution type) than interactions with low visual novelty objects. Error bars depict ±1SE.

While a significant main effect of solution type was not found, this null effect suggests that the current experimental procedure and design, offered balanced support for both the generation of NSP recognition (1.17 solutions) and NF solutions (0.96 solutions). This however does not mean that our experimental procedures did not influence the occurrence of each solution type. Despite failing to find a main effect of Instruction type ($F_{(2,71)} = .019$, $p = 0.987$), we did find evidence that this is likely because of a significant interaction between Instruction type and Solution type, such that as the level of overt instruction to problem solve increased, (1) the occurrence of NF solutions increased (NoPS: 0.56 solutions, BroadPS: 0.965 solutions, SpecificPS: 1.35 solutions), while (2) the occurrence of NSP recognition decreased (NoPS: 1.54 solutions, BroadPS: 1.19 solutions, SpecificPS: .78 solutions) (See Figure 3). A post-hoc one-way ANOVA examining NSP occurrence across the 3 types of instruction (Plotted in Blue, Figure 3) was performed and found to be significant ($F_{(2,71)} = 7.093$, $p = 0.002$; Observed Power= 0.920; Partial Eta Squared = 0.167). A LSD test revealed that the SpecificPS condition yielded significantly less NSPs than the BroadPS condition (Mean difference = -0.41, SE = 0.199; $p=0.043$) and NoPS condition (Mean difference = -0.76, SE = 0.201; $p<0.001$). Similarly, a post-hoc one-way ANOVA examining NF solution occurrence across the 3 levels of instruction (Plotted in Green, Figure 3) was performed and found to be significant ($F_{(2,71)} = 4.173$, $p = 0.019$; Observed Power= 0.717; Partial Eta Squared = 0.105). A LSD test revealed that the SpecificPS condition yielded significantly more NF solutions than the NoPS condition (Mean difference =

0.79, SE = 0.272; p=0.015). The notion that NSP occurrence was suppressed as the level of explicit instructions to problem-solve was increased is consistent with our view that constraints to the affordance landscape will hinder need-solution pair recognition (see Hypothesis H1a). According to our framework, an actively considered problem constrains attention to those affordances that are pertinent to the considered problem. In reference to NSP recognition, this constraint to the affordance landscape should place limits on NSP recognition as it hinders broad consideration for function. It is also meaningful that our instruction manipulation yielded a drastically different effect on NF solution behavior than NSP recognition (see Hypothesis H1b, Figure 3). As previously mentioned, NF solution occurrence significantly increased while NSP recognition decreased as the level to explicitly problem-solve was increased. This crossover interaction indicates that the scope of the affordance landscape differentially affected NSP and NF processes, highlighting that they represent distinct cognitive processes.

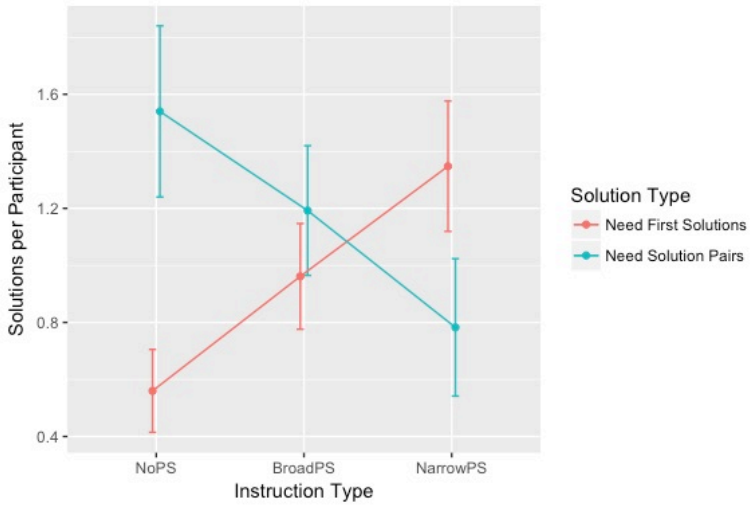

Figure 3: As overt instruction to problem-solve increases, it differentially affects the occurrence of NSP and NF. NSP occurrence significantly decreases while NF solution occurrence significantly increases. Error bars depict ±1SE.

Solution Type was also found to interact with Object Novelty ($F_{(1,71)} = 16.494$, $p<0.0001$) indicating that the occurrence of NSP were significantly more impacted by Object Novelty than the occurrence of NF solutions. Specifically, the occurrence of NF solutions rose from 0.59 solutions to 1.32 solutions (an increase of 0.73 solutions) when exposed to visually novel

objects, while the occurrence of NSP rose from .33 solutions to 2.01 solutions (an increase of 1.68 solutions) (See Figure 4). Post-hoc paired sample t-tests revealed that the effect of Object novelty on NF occurrence ($t_{(73)} = 4.967$, p. .001) and NSP occurrence ($t_{(73)} = 9.471$, $p<.001$) was significant. While the significant main effect of Object Novelty indicated a general pattern to suggest that interactions with visually novel objects yields more solutions than interactions with visually familiar objects, the significant interaction term between Solution Type and Object Novelty suggests that the effect of Object Novelty was much more pronounced for NSP than NF problem solving. This effect was anticipated due to our view that NSP recognition relies more heavily on ad hoc affordance processing than does NF problem-solving.

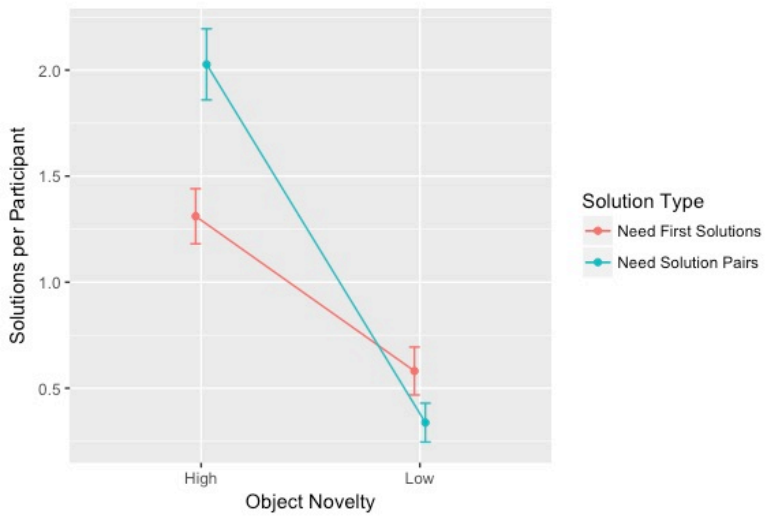

Figure 4: Interactions with novel versus familiar objects differentially affects the occurrence of NSP and NF. NSP occurrence significantly decreases while NF solution occurrence significantly increases. Error bars depict ±1SE.

Of the remaining terms in the model, the only other significant term found was between Object Novelty and Instruction Type ($F_{(2,71)} = 3.782$, $p<0.028$). This interaction suggests that the impact of Object Novelty on solution finding was differentially effected by the level of instruction to explicitly problem solve. More specifically, Object Novelty was found to have the biggest impact on the occurrence of solutions (either NSP and NF) in the NoPS condition, and that this impact was lessened when individuals were given either Broad or Specific instructions

to explicitly problem solve. (See Figure 5). Post-hoc paired-sampled t-tests (adjusted for multiple comparisons) revealed that the Object Novelty manipulation yielded a significant difference in the occurrence of solutions for each Instruction Type (collapsed across NSP and NF solutions). (Bonferroni's t-value adjustment for 2 sided testing at the 0.05 alpha level needs to exceed -2.5912, or 2.5912 ; NoPS condition $t_{(22)}$= -9.070, BroadPS condition $t_{(22)}$= -5.943; SpecificPS condition, $t_{(22)}$= -4.347). This finding suggests that Object Novelty is a critical factor in invoking solutions when participants are given no instructions to explicitly problem-solve. While solution generation can improve in low novelty setting with more instruction to explicitly problem solve, the reverse is seen in high novelty settings. Specifically, solution generation suffers in high novelty environments as instruction to problem solve becomes more specific. The data are compatible with view that while highly novel environments may stimulate affordance processing, active consideration of a problem under such circumstances acts only as a constraint on such processing, which in turn hinders solution finding (either by NSP or NF). The converse however appears to be true: while in low novelty environment, active consideration of a problem may be necessary in order to evoke solution-finding (either by NSP or NF).

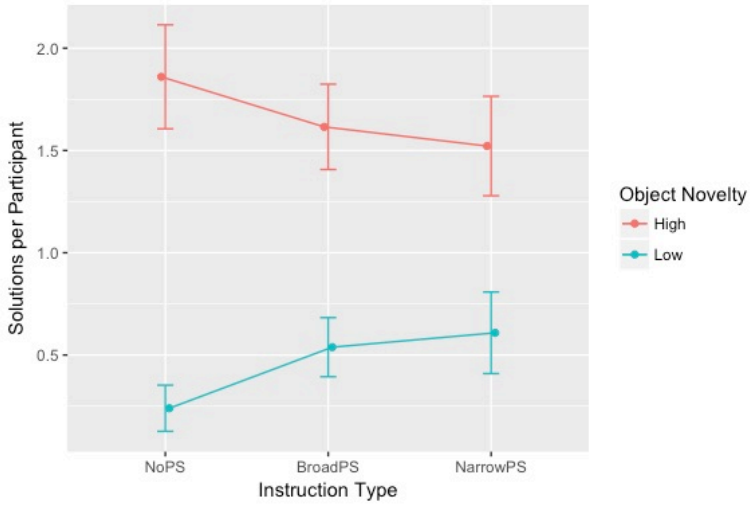

Figure 5: Object novelty (low vs. high) has the largest impact on solution generation in the NoPS condition, where participants were told to simply explore the room. Error bars depict ±1SE.

4.3 Object novelty in triggering need-solution pairs vs. need-first solutions

Recall that participants were asked to identify the objects or groups of objects that appeared to trigger their solutions (either NSP or NF) in our post-session interviews. In 90% of the instances, our participants were able to identify an interaction with an object in the setting that led to their solution (either NSP or NF). For each object, raters were asked to rank how novel the item visually looked. For details on this assessment process, see section 3.4.3. We then looked to see if there was a relationship between the novelty of an object's appearance and how often it acted as a trigger object for NSPs (see Hypothesis H2b). A regression between the two measures, using the Huber/White correction for heteroskedastic errors, revealed a positive, significant relationship ($t_{(68)} = 2.87$, $p<0.01$), indicating that the occurrence of NSP identification is linearly related to the visual novelty of objects, such that more visually novel objects have a significantly greater likelihood of eliciting NSPs than visually familiar objects (see Figure 6a; White, 1980). We did not find evidence for a relationship between the visual novelty of an object and how often it elicited NF solutions (Huber/White corrected, $t_{(68)} = 0.6941$, $p=0.49$, Huber/White corrected) (see Figure 6b). This finding further supports the notion that object familiarity discourages ad hoc affordance processing (due to functional fixedness), which we have argued supports NSP recognition.

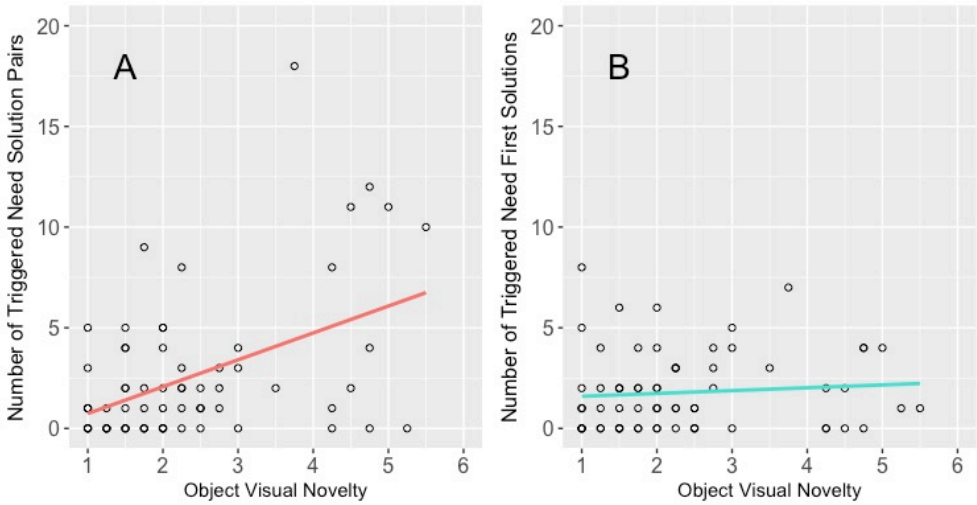

Figure 6. Linear associations visual novelty rating for an object and the number of solutions it triggered (Panel A: NSP, Panel B: NF). The solid lines represents the line of best fit. Results indicate that objects that are more visually novelty are significantly more likely to trigger NSPs (Panel A). No such relationship however was found between visual novelty and NF occurrence (Panel B).

4.4 The creativity, novelty, and general value of solutions recognized by our participants

Recall that, in hypothesis H3, we reasoned that solutions resulting from NSP recognition would be higher in creativity and novelty than solutions resulting from need-first problem-solving. We used independent coders, as was discussed in our methods section, to evaluate both the need-solution pairs (n = 175) and the NF solutions (n = 138) generated by our participants with respect to novelty and creativity. In addition to novelty and creativity, we also assessed the value of each solution as proposed by de Jong et al. (2015). To assess if (1) the explicit instruction to problem-solve, (2) the presence of object novelty or (3) solution type influenced the creativity, novelty or value of solutions generated, we utilized a 2 (Object Novelty: Low vs. High – within subjects) x 3 (Instruction type: NoPS, BroadPS, SpecificPS – between subjects) x 2 (Solution Type: NSP count vs. NF solution count – within subjects) multivariate analysis of variance on the three dependent measures of solution creativity, solution novelty, and solution value.

In support of hypothesis H3, we found a main effect of Solution Type for the dependent measures of solution creativity ($F_{(1, 301)} = 13.834$, $p<.001$) and solution novelty ($F_{(1,301)} = 12.431$, $p<.001$). Examination of the means demonstrates that the assessed creativity and novelty was higher for NSP than for NF solutions (See Figure 7). In addition to the main effect of Solution Type, a main effect of Instruction type was also found for the dependent measures of solution creativity ($F_{(2, 301)} = 8.694$, $p<.001$) and solution novelty ($F_{(2, 301)} = 8.213$, $p<.001$), indicating that at least one of the three instruction types yielded solutions with significantly different creativity and novelty. A post-hoc LSD multiple comparison test indicated that the assessed creativity and novelty of solutions generated in the SpecificPS condition was lower than solutions generated in either the BroadPS (mean difference: -0.6421, SE: 0.131, $p<.001$) or NoPS (mean difference: -0.06790, SE: 0.132, $p<.001$) conditions (See Figure 8).

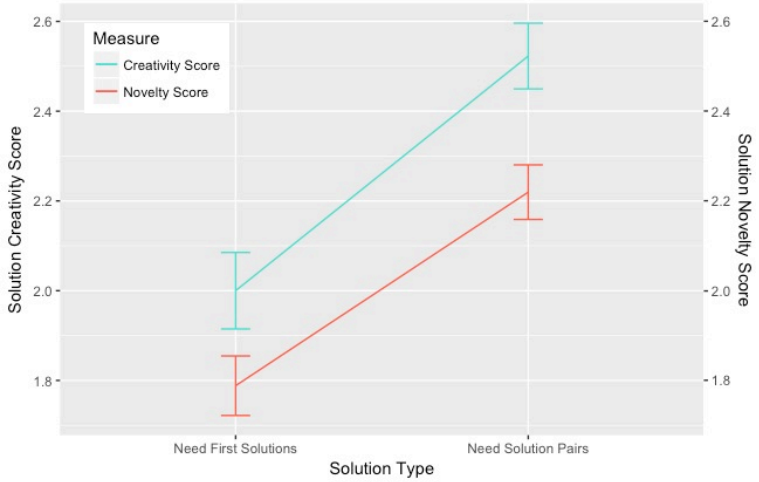

Figure 7: Assessed creativity (in blue, left axis) and novelty (in red, right axis) was higher for NSP than for NF solutions. *Error bars depict ±1SE.*

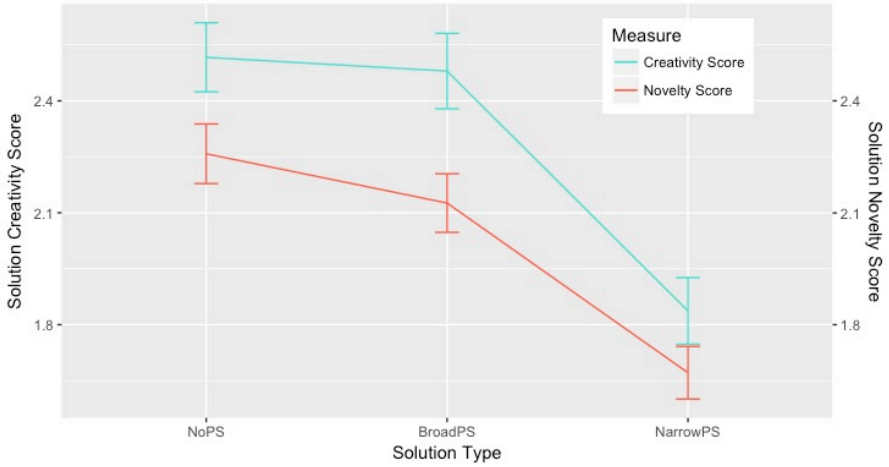

Figure 8: Solutions generated in the SpecificPS condition had lower assessed creativity (in blue, left axis) and novelty (in red, right axis) than solutions generated in either the BroadPS or NoPS conditions. *Error bars depict ±1SE.*

While we did not have a direct hypothesis about solution value, we did find a significant main effect of Object Novelty for the dependent measure of solution value ($F_{(1,301)} = 16.766$, $p<.001$). Solutions found in low object novelty environments are assessed to have higher value (mean = 3.151, SE = 0.098) than those found in high object novelty environments (2.714, SE = 0.042).

Importantly however, we failed to find a significant difference in the general value of solutions recognized via NSPs, and those discovered via a NF process ($F_{(1,301)}$= 0.817, p = 0.367). While we did not hypothesize this outcome this result highlights that NSP and NF solutions generated in this experiment appear to hold the same general value, independent of solution type.

Lastly, a significant interaction effect between Object Novelty and Solution Type for the dependent measure of solution creativity ($F_{(1,301)}$ = 4.454, p = .036) was found. Inspection of the means indicate that while solutions from NSPs have higher creativity than NF solutions, that this difference is exaggerated in the low object novelty condition (See Figure 9). A similar trend, although only marginally significant, was found for the dependent measure of solution novelty ($F_{(1,301)}$ = 3.333, p=0.069). These results demonstrate that solution-finding by NSPs appears to allow individuals to use familiar objects in novel ways, while solution-finding that is NF encourages individuals to use familiar objects in familiar ways. While this result was not necessarily anticipated, it does demonstrate that both forms of solution-finding are influenced by the functional understanding of objects.

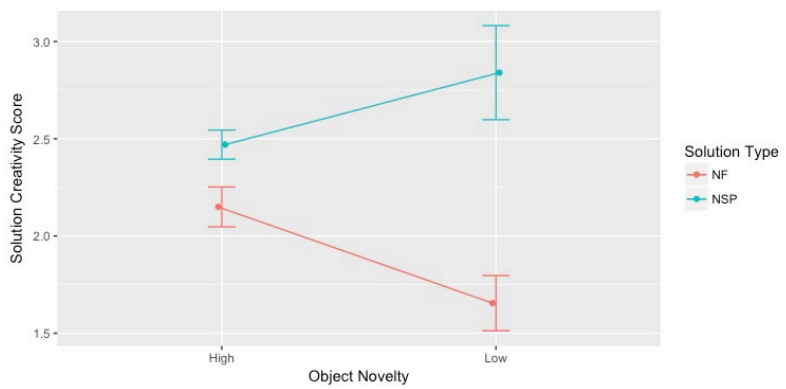

Figure 9: While NSP solutions demonstrate higher creativity scores than NF solutions, this difference in creativity is exacerbated in the low object novelty condition. Error bars depict ±1SE.

5. Discussion

The main contributions of this paper have been (1) to produce empirical evidence for the occurrence of NSP recognition, (2) to provide examination of a cognitive account for how NSP recognition may arise, and (3) to assess the creative value of NSP recognition relative to NF

solution-finding. As we have previously discussed, solution-finding has been traditionally conceived of as a process that begins with the identification of a need or problem, followed by attempts to solve it (Newell & Simon, 1972; Sternberg & Frensch, 2014). The contributions of this current study however, challenge this traditional conception. Rather than postulate that solution-finding is a product of a NF process, the cognitive account supported by our data suggests that solutions may also arise from the functional consideration of objects. Moreover, solutions found by NSP were found to be more creative and novel than solutions found by a NF process, highlighting that the practice of NSP recognition may be best suited to situations requiring highly innovative solutions.

5.1 Evidence for NSP recognition and its potential pervasiveness

Our results demonstrated that not only do solutions by NSP recognition occur, but that they occur just as frequently as solutions found using a NF strategy. While this suggests that our current experimental procedure and design, as a whole, balanced support for the generation of both NF (0.96 solutions) and NSP solutions (1.17 solutions), it offers some indication that NSPs may be just as ubiquitous in practice as NF solution-finding despite a lack of awareness heretofore for its occurrence. We contend that the lack of awareness for NSPs in both practice and in research up until this point likely stems from confirmation bias – nothing more than an unwitting or unconscious selectivity for (or revision of) evidence to fit with the traditional view that solutions only arise from problems. Our demonstration of need-solution pairs should therefore be taken as proof of concept that solution-finding need not always start with a problem.

5.2 Functional object understanding as a general mechanism for solution-finding

The results of the current experiment also offered an examination of the cognitive architecture that supports NSP recognition. This was accomplished by examining how the spontaneous occurrence of NSPs was affected by the manipulation of both (1) object familiarity and (2) explicit instructions to solve specific problems. These factors were manipulated so as to assess the degree to which the functional understanding of objects affects the occurrence of NSP recognition. Our results demonstrated that NSP occurrence was highest when individuals were

told to simply explore an environment with no explicit instruction to problem-solve. We also found that NSP recognition occurred significantly more when participants were presented with novel objects. The notion that visual object novelty directly supported NSP recognition in our study was also corroborated by the significant positive relationship found between an object's assessed visual novelty and the number of times the object triggered a NSP insight.

5.2.1 Unconstrained, undirected attention supports NSP processing. Why would NSP recognition be best supported when individuals are told to simply explore an environment? One possible explanation that we have explored here, is that freedom from an actively considered problem might allow one greater access to the full affordance landscape. This is because having a specific problem in mind likely directs attention towards particular functions or aspects of objects that relate to the specific problem at hand. Under this view, the specific problem being pursued acts as an attentional filter for the recognition process, constraining how one approaches the affordance landscape. When participants are unencumbered by a specific problem, attention can be more diffuse, allowing them to reason more fully about the objects they may encounter. This suggests that NSP recognition may flourish under situations involving open monitoring, a mental state where individuals are not focused on any particular concept, item, or goal (Tang, Hölzel, & Posner, 2015). Consistent with this view are results from previous research, which has demonstrated that individuals who regularly practice the open-monitoring of attention (through open-monitoring meditation) are better at overcoming effects associated with functional fixedness than those that practice focused-attention (through focused-attention meditation) (Colzato et al., 2012).

5.2.2 Object novelty supports NSP processing. We also found clear evidence that interactions with objects with high visual novelty lead to significantly more NSPs than interactions with low visual novelty. Further, a significant positive relationship was found between an object's assessed visual novelty and the number of times the object triggered a NSP insight. Why would object novelty support NSP recognition? As previously discussed, past research has shown that affordance processing becomes more rigid and tied to past experience once a particular usage for an object has been reinforced (Duncker, 1945). From this perspective, familiar objects naturally suppress ad hoc affordance processing (due to functional fixedness),

which necessarily constrains the affordance landscape, hindering NSP recognition. While the effect of object novelty is strongest on the occurrence of NSP recognition (as evidenced by a significant interaction between object novelty and solution-type), the overall significant main effect of object novelty indicates that both types of solution-finding are beholden to the same object recognition mechanism, just to differing degrees. This finding suggests that, in a very general sense, solutions appear to emerge from the functional consideration of objects, whether constrained or unconstrained by a problem. This observation highlights that the cognitive mechanism put forth here for NSP recognition can be parsimoniously extended to NF solution-finding, and can for example, be utilized to offer insight as to why functional fixedness hinders traditional problem-solving (Adamson, 1952; Allen & Marquis, 1964; Chrysikou & Weisberg, 2005; Duncker, 1945; Luchins, 1942; McCaffrey, 2012).

5.2.3 NSP processing with non-physical entities. While the current work utilized physical objects to examine NSP recognition and NF solution-finding, it is our view that our results will generalize to other kinds of objects, provided that individuals can reason about their affordances. Despite not being tangible entities, it seems sensible that one can reason about the function of a given process, a given procedure, a given algorithm, or even a given idea and from such reasoning, come to understand the given entity (or aspect of the entity) as a solution to a previously unknown problem. For example, while genetic hill-climbing algorithms were initially used to model the process of natural selection, they have had application in a number of disparate areas such as the optimization for traffic routing (e.g., the 'Traveling Salesman Problem'), coding breaking and even the generation of virulent Internet memes. While some of these applications may have been generated via a NF process, it is conceivable that some are the result of NSP recognition - happened upon only through the consideration of the algorithm's function (consciously or unconsciously). Beyond the call for further work to demonstrate that NSP recognition can occur for non-tangible objects, it will be important to determine if the functional consideration of such non-tangible objects is similarly affected by conventional usage so as to determine if solution-finding with non-tangible objects is also hindered by functional fixedness.

5.3 Solutions found by NSP recognition are perceived to be more creative and novel than solutions found by traditional problem-solving.

NSPs were found to have higher creativity and novelty than those recognized as NF solutions. This finding was in line with our hypothesis that conditions that allow NSP recognition to thrive (No explicit instruction to problem-solve and high visual object novelty) would also be suitable for supporting creative analogical reasoning and less functionally fixed affordance processing. Work by Sternberg (1977) as well as work by Holyoak and Thagard (1995) both have argued that analogies that bridge larger semantic distances are generally perceived as more creative than those that bridge smaller distances. This is because distant analogies by definition allow for juxtapositions that illuminate features of objects or ideas that are novel. Indeed, work by Christensen and Schunn (2007) has demonstrated that interactions with familiar objects often inhibit analogical reasoning due to functional fixedness.

5.4 NSPs as a new form of insight processing

According to participant self-report, solutions by NSP recognition were accompanied by a subjective "aha" or "eureka" feeling, which could prompt the comparison of NSP recognition to insight problem-solving (or NF insights). While solutions found via NSP recognition also appear to occur spontaneously, similar to NF insights, we hold that NSP recognition is a markedly distinct form of insight. According to research on NF insights, there is empirical evidence to suggest that in order for an NF insight to be achieved, one must first attempt to solve a problem that results in an impasse (i.e. a failed attempt at solving the problem). Indeed, research by Vul and Pashler (2007) has demonstrated that need-first insights only occur if one initially uses an inappropriate strategy or are initially given misdirecting information when approaching a problem. Simply formulating or hearing the problem is not enough. This suggests that the occurrence of NF insights relies not only on explicit problem formulation, but a clear previous attempt, met in failure, to solve a problem. This aspect of NF insights is not compatible with the NSP insights observed in our experiment, and as such suggests that NSP insights are precipitated, at least in part, in a different manner from NF insights.

5.5 Suggestions for further research

Our research has demonstrated that solutions appear to generally emerge from the functional understanding of objects. Given the fundamental importance of solution-finding to individual and social functioning and progress in general, it would clearly be useful to conduct research to more deeply understand this form of thinking. A few suggestions to this end follow.

First, in future research, it will be important to better understand the suppressive effect that pre-specification of a problem has on solution-finding in general, especially with regard to NSP solution-finding. Experimenters who engage in NF experiments will generally not provide a path to noticing or documenting NSPs that may nonetheless be occurring within their experiments. For example, an experimenter who asks individuals to "list all the words they can bring to mind that begin with the letter C in two minutes" will not consider asking about or documenting an NSP that might be evoked in a participant's mind due to an object that happens to be present in the experimental setting. Similarly, an experimenter who presents Dunker's classic candle problem to participants in order to observe how they solve it will not be primed to notice or document an NSP that might occur to some participants in that setting. For many research purposes, it will certainly be useful to pre-specify a problem and limit inquiry to only solutions that satisfy that given problem. Still, when exploring NSPs and the role of object recognition, it will be important to treat pre-specification of a research problem not as a given, but as an experimental variable.

Beyond simply being aware that NSP processing may be occurring in NF contexts, it will be important to look beyond the situational effects observed here to have an effect on NSP occurrence and examine how individual differences in both the neural and cognitive factors may also impinge on NSP processing. For example, at the neural level previous work has demonstrated that activity in frontopolar cortex (FPC) supports analogical coupling (Holyoak & Thagard, 1995; Mayer, 1999) and therefore, may in part explain individual differences in NSP processing. Similarly, individuals with high working memory (WM), or a strong ability to actively maintain information for the purposes of ongoing cognition, have been shown to possess better analogical reasoning (Corkill & Fager, 1995; Novick & Holyoak, 1991; Stanovich, 1999). As such, individual differences in WM may explain meaningful inter-individual differences in NSP processing. Beyond better understanding for the neural and cognitive factors that may support NSP recognition, it also remains an open scientific question as to whether individual differences in NSP processing reflect some biological endowment or whether they are

themselves the result of experience and as such can be influenced by training and practice.

We also wish to note that future work should be cautious with respect to equating NSP recognition with the phenomenon of 'serendipity.' Serendipity, sometimes refers to as "accidental sagacity" was first devised by Horace Walpole in 1754 in reference to a Persian fairy tale entitled "The Three Princes of Serendip" in which the three princes were "always making discoveries, by accidents and sagacity, of things which they were not in quest of…" (Walpole, 1937, p. 408). As Walpole noted, "you must observe that no discovery of a thing that you are looking for comes under this description" (ibid., p. 408). Moments of serendipity have been noted in the histories of many important advances. For example, discovery of the first synthetic dye by William Henry Perkins came about quite 'serendipitously' in 1856 when he was seeking a solution to an entirely different problem - a way to make synthetic quinine to treat malaria. During his attempts to synthesize quinine, a chemical compound he created serendipitously displayed a rich, purple color. Perkins recognized this serendipitous outcome as a potentially very valuable synthetic dye – a solution "he was not in quest of"(Ban, 2006). Similarly Velcro was reported by its inventor, de Mestral, to arise from an experience he had with a plant burr that stuck to his clothing, where he recognized the mechanism of how the burr clung to fabric as a new way to design fasteners. Both the need and the solution were novel to him at the time of his discovery (Cunha, Clegg, & Mendonça, 2010). More generally, it is a known element of research project histories that scientists can be sufficiently influenced by 'serendipitous' discoveries to redirect their solution search on new paths and/or restructure their problem specification (Foster & Ford, 2003, p. 334). While NSPs may be classified as a 'serendipitous' as in the case of Velcro, the label (at least historically) however, offers little insight into the mechanisms that may underlie its occurrence. Indeed, the approach to serendipity has been largely phenomenological, with some scholars including NF insights, or the unexpected discovery of a solution to a problem already being worked upon, as an accepted form of serendipity (for a full taxonomy of serendipity, see Yaqub, 2018). The notion that NF insights can be thought of as examples of serendipity highlights clearly that NSP recognition and serendipity are not synonymous with one other.

5.6 Suggestions for organizational practice

At the organizational level, there are clear lessons to be derived from our findings. Broadly speaking, problem-solving organizational practices and incentives explicitly or implicitly assume a pattern in which needs are first identified, and then problem-solving follows. For example, Spradlin (2012, p. 85) echoes commonly held belief in his reproach that "most companies aren't sufficiently rigorous in defining the problems they're attempting to solve and articulating why those issues are important… Many organizations need to become better at asking the right questions so that they tackle the right problems." What we have shown in this paper is that NSP solution identification *without* prior identification of a problem can also produce creative and valuable solutions. We therefore suggest that under some conditions, organizations should consider enabling, gathering, and using solutions developed as NSPs. To this end, we recommend as a first step, the identification of functional "objects" possessed by the organization, which could be utilized to trigger NSP recognition. While our work focused on physical objects, we hold that our results will generalize to other kinds of objects such as processes or algorithms. Given that our results showed that interacting with familiar objects may severely hinder NSP recognition, it will be important for those attempting to utilize NSP recognition for innovative purposes to employ strategies that help to minimize effects associated with functional fixedness (e.g., McCaffrey, 2012). Further, as not specifying a problem resulted in a higher likelihood of generating NSPs, strategies associated with the open-monitoring of attention (e.g. Tang & Posner, 2009) may also prove to be important for cultivating NSP recognition.

While we did not find a difference in the assessed "value" of solutions generated by NSP and those generated NF, it remains true that what is valuable to one organization or individual is not necessarily valuable to another. For this reason, solutions generated by NSPs must be filtered *post-hoc* to identify those that are valuable to a specific individual or firm. For NF problem-solving, the assignment of value for any given solution or solution path is accomplished during the problem-solving process itself (E.g., "My firm is likely to get X value from creating a solution to Y problem. If this value is sufficient, we should go ahead and invest in the problem solving phase"). When using NSPs in an organizational setting, it will be vital to follow the generation of NSPs with a filtering procedure to identify the narrow subset of NSPs that can offer value to the organization in which they occur.

Clearly, to be a worthy complement to NF problem-solving within firms, NSP generation must provide potentially profitable "hits," with sufficient frequency to justify the investment in producing them. The likelihood that NSPs generated will be of value to an individual or to a firm can be increased in two ways. First, in the case of our experiment, presenting individuals with novel objects that are related to specific interests or business areas seems to increase the likelihood that the NSPs identified will fall within that general area. For example, in our experiments we situated our participants in a domestic (Airbnb) setting, and offered them access to a cabinet containing novel objects likely to have domestic uses. Possibly as a result, most of the affordances these objects offered were domestic ones, and/or possibly the relevant background and experiences of our experimental participants had a bias towards recognition of affordances applicable in the domestic sphere. In any case, approximately 90% of NSPs generated in our experiments did involve domestic functions.

Specialized firms wishing to experiment with NSP recognition as an alternative solution finding practice can take courage from the implication that to some extent NSP problem solving can be channeled by context into directions of value to the firm or organization by the appropriate selection of objects and/or by the selection of individuals with appropriate backgrounds to be asked to generate NSPs. Second, it seems reasonable that supporting need-solution pair recognition will produce a higher "hit rate" of valuable results under conditions where a wider range of solutions are of interest. At the individual level, this criterion seem especially applicable to leisure-time activities, where "anything that will be fun" or otherwise of value could be a viable candidate. In the case of producers, this criterion seem especially applicable in the case of entrepreneurial opportunity recognition (Kirzner, 1979, 1999), where no application-specific investments have yet been made, and where "anything that can make money" could be a viable NSP.

Overall, there seem to be significant possibilities that deploying NSP generation can be useful at both the individual and organizational level of practices, provided that care is taken that such applications are guided by an understanding for the mechanisms that support NSP. Just as clearly, further research and experimentation will be required to reach this potential.

5.7 Conclusion

In this paper, we have demonstrated behavioral evidence for the occurrence of NSP recognition, a new form of solution finding that occurs when the consideration of a given object's function leads to discovery of both a solution and a need it satisfies without the demand for previous problem formulation. In this demonstration we have shown that NSP recognition is observed more frequently in environments with unfamiliar objects, where participants were *not* directed to solve specific problems. Further, we have shown that solutions obtained by NSP recognition were found to be significantly more creative and novel than solutions generated pursuant to a "need-first" problem-solving process. Taken together, our research supports the view that NSP recognition is likely a highly prevalent and innovative form of solution-finding that emerges from the natural capacity of perceivers to consider (consciously or unconsciously) the functions of objects.

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