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Board 344: Neural Correlates of Learning Preferences and Individual Differences in Design Fixation: Preliminary Evidence from Functional Magnetic Resonance Imaging (fMRI)

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Introduction

Problem solving in design is frequently susceptible to fixation, restrictions and mistakes introduced in the design process due to previous practice, that often impede the generation of effective design solutions. Research has shown that the inclusion of examples in the problem's instructions is associated with a tendency to conform to those examples during creative generation, a phenomenon known as *design* fixation [1], [2]. Individual differences in learning tendencies during concept building might underlie one's susceptibility to design fixation. In this exploratory study, we investigate how learning tendencies relate to the neural correlates of performance on a design fixation task relative to a control design task, using a multimethod approach.

We hypothesize that an exemplar-based approach to learning—reflected in brain activity patterns—will reinforce the impact of examples in design tasks, by increasing the salience of the example design features relative to the abstract relationships that unite them. In contrast, an abstraction-based approach to learning—reflected in different patterns of neural activity—may emphasize the abstract design rules governing the example designs, thus offering protection from design fixation to their features. Based on prior literature, we further hypothesize [1], [2], that differences in domain expertise between mechanical engineering and product design would mitigate these effects.

Method

Overview & Design: Mechanical engineering and product design undergraduate students participate in two experimental sessions. In the first session, they complete multiple behavioral learning tasks and individual differences assessments; in the second session, they undergo a functional magnetic resonance imaging scan (fMRI) while completing a computerized learning task, as well as two design tasks using a drawing tablet compatible for the brain imaging environment. Participants' thought processes are also captured through concurrent verbal protocols during the scan that are obtained using an MRI-compatible noise-canceling microphone.

During the first session, participants' learning preferences are recorded by means of the Function Learning Task. During the second brain imaging session, participants' learning preferences and the neural differences underlying them are recorded by means of the Category Learning Task. During this session, participants also complete two design tasks while undergoing brain imaging and while thinking aloud. These tasks as described more extensively below.
In the Function Learning Task (FLT), participants are asked to learn to predict the relationship between a novel input and output stimuli, which follow an inverted-V function form ($y = 2.196x+14.81$ for x </= 80 and $y = 364.97-2.195x$ for $x > 80$ rounded to the nearest whole

number. Immediate feedback is given during practice blocks, allowing participants to learn the true output via guess and check. For each training block, a participant views an input, predicts the output, and receives feedback (see Figure 1). After training, all participants complete a test block, consisting of 6 pairs of interpolation and 30 pairs of extrapolation stimuli. No feedback is provided during the testing block [3], [4].

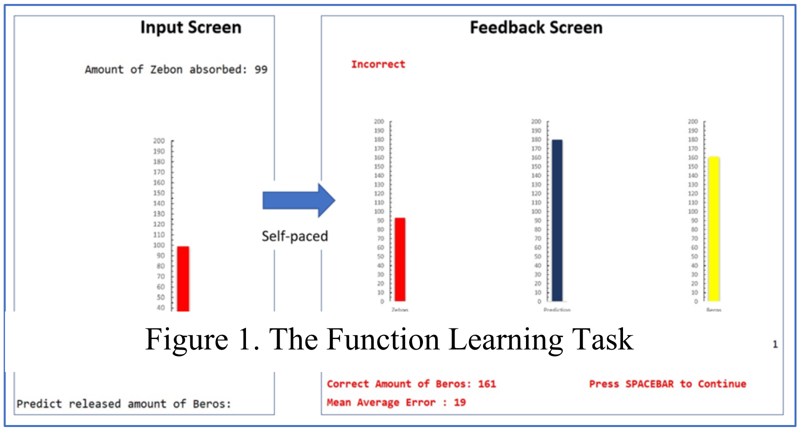

Figure 1. The Function Learning Task

In the Category Learning Task (CLT), participants are asked to learn to predict the category of fictitious animals (*builders* or *diggers*) based on a three-feature additive rule (Figure 2). Immediate feedback is given during training blocks. After training, participants complete a test block, consisting of 8 trained stimuli and 8 novel (i.e., untrained) stimuli. No feedback is provided during the testing block [5].

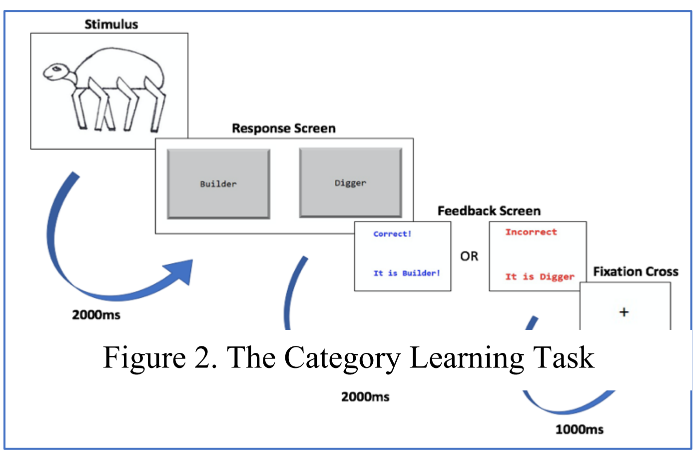

Figure 2. The Category Learning Task

For the design fixation and control design tasks, participants are asked to generate solutions for two design problems, the Bike Rack problem and the Coffee Cup problem [6], while undergoing fMRI. Participants see either the verbal description of the problem along with a pictorial example design with some explanation of that design (fixation), or the verbal description of the problem alone (control) [6]. Design responses and verbal protocols are collected during the tasks. The entire session is recorded on Zoom. The imaging session takes place in a 3T Siemens PRISMA scanner at the Temple University Brain Imaging Center (TUBRIC), and it includes the Persaio® noise-canceling microphone and the Hybridmojo drawing tablet.

Preliminary Results

Our preliminary results confirmed that the experimental problem was significantly more likely to elicit design fixation relative to the control problem ($t(4) = 7.53$, $p = .002$). A statistically reliable difference in the presence of design fixation was also found between exemplar and abstraction learners, with exemplar learners showing increased design fixation relative to abstraction learners ($t = 7.54$, $p = .009$), in line with our predictions. Our brain imaging results were analyzed using FSL [7] and followed standard procedures; models of brain imaging activity were constructed based on events in the design processes that were elicited from the concurrent verbalizations and coded by three independent rates according to the Function Behavior Structure (FBS) ontology for design [8]. The preliminary analysis of the task-based imaging results points to neural differences in posterior parietal integration regions between function, structure, and behavior, which did not significantly correlate with learning style, likely due current sample size limitations.

Discussion

Our exploratory study findings suggest that learning tendencies (toward being an *exemplar* vs. *abstraction* learner) and their neural correlates may contribute to susceptibility to fixation. This preliminary finding, if confirmed with a larger sample, lays the foundation for a fuller understanding of fixation related to an individual's learning style. The project is ongoing with further data being collected to produce a larger sample size and a full analysis of the data to be carried out to confirm the preliminary results in detail. Design fixation is a significant barrier to the generation of new design ideas and solutions. Understanding how to break away from these effects has potentially important implications for engineering design education and engineering design practice. Fixation is also a factor in problem solving in many fields, so the results from this NSF-funded project have impacts beyond engineering education.

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