Interventions for Ideation

Impact of Framing, Teaming, and Tools on High School Students' Design Fixation

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Abstract: Expert engineers are fluent at proposing many conceptual ideas early on in their process for solving a design problem. Beginning engineers are more likely to fixate on one or only a few ideas. Interventions aimed at this stage of the design process could help make it easier for beginning engineers to generate ideas that go beyond their initial ones. An experimental design tested the impact of four interventions on the ideation process of high school students: (1) *Adaptive Framing*, (2) *Innovative Framing*, (3) *Teams*, and (4) *Tools*. There was not a significant positive effect on the number of ideas generated or on participants' perceived difficulty in generating ideas in any of the four interventions. Results suggest that further work needs to be conducted to improve these interventions so that they positively impact the ideation processes of beginning engineers.

Objectives

Idea generation – or ideation – is critical to the success of engineering practitioners. Ideation occurs most notably in the early stages of design, when engineers propose solutions that they will later explore and refine (or reject). Ideation impacts the success of the overall design process as the quality of those early conceptual ideas bounds and limits the final solutions. The larger goal of our research is to understand and improve how engineering students engage in ideation. This study's objective was to set the groundwork for assessing the impact of interventions intended to improve the ideation process. In this initial work, we started with high school students who had shown interest in engineering as a career and considered four ideation interventions: (1) adaptive framing, (2) innovative framing, (3) teaming, and (4) tools. Our research question was: What impact does each intervention have on making it easier for beginning engineers' to reduce their tendency to fixate on a small number of ideas?

Theoretical Framework

In their review of learning trajectories from beginning to more informed engineering practices, Crismond and Adams (2012) found that a key distinction in ideation is between *idea scarcity* and *idea fluency*. Beginning engineers start their design process with a scarcity of ideas, often only considering one or a few. In contrast, expert engineers do a thorough exploration of the space of possible design solutions. Their fluency with multiple possible ideas minimizes the chance of fixation, which is the tendency to focus on specific options or ideas early in the design process (Purcell & Gero, 1996). Expert engineers often employ structured techniques for generating a

diverse set of ideas. One approach for helping beginning engineers to reduce their tendency to fixate on a small number of ideas is to translate these ideation techniques into interventions and test their impact.

One possible intervention focuses on an individual's task *framing*. An engineer's framing includes an expectation about the problem solving approach that is called for in a situation. Cross (2004) describes how expert engineers actively explore the space of possible design solutions by defining the problem and solution together. In contrast, beginning engineers often frame design problems as calling for deductive reasoning and analysis leading to one solution. By carefully wording the problem description, it is possible to actively frame the design context so the engineer is focused on generating a range of solution ideas. At a basic level, all engineering design problems have a description of the background context and a needs statement. A *neutral* framing may include that information and nothing more. Adding a solution-focused frame could be accomplished by adding explicit instructions to encourage either an *adaptive* framing—promoting solutions that build on and improve existing solutions and ways of thinking about a context—or an *innovative* framing—promoting novel solution ideas that tend to relax constraints. Either framing may encourage beginning engineers to adopt a solution focus more readily than a *neutral* framing, and in turn make it easier for them to generate more ideas.

A second possibility is that the main limitation for beginning engineers may be related less to their general ideation approach, and more to limitations of their prior knowledge in particular design contexts. One way to overcome such limitations is to have engineers work in *teams* in which each participant brings a different set of experiences. Attending to each other's ideas (Paulus & Yang, 2000), the team may be able to overcome individual limitations, and therefore make the task of generating multiple ideas easier.

A third possibility is that an individual may have sufficient prior experience, but may not recognize the applicability of their experiences within particular problem contexts. In this case, the engineer could benefit from a *tool* to encourage them to make connections to broader areas of their knowledge base. One such tool is *Design Heuristics Cards* (Daly, Yilmaz, Christian, Seifert, & Gonzalez, 2012), which are cognitive prompts printed on a set of hand-held cards. Each card includes a description of a strategy used by expert engineers to generate alternative solutions ideas. Using this tool may help participants generate additional ideas even after they feel they have exhausted their initial ideas.

Taken together, these interventions represent a range of approaches to helping beginning engineers overcome their tendency to fixate on a small number of ideas (Figure 1). By assessing these interventions in terms of the number of ideas generated by high school students in an engineering design context, as well as students' perception of how difficult it was to generate ideas using the interventions, we can begin to understand their impact on the ideation process. Although there are a number of metrics for evaluating ideation effectiveness (Shah, Smith, & Vargas-Hernandez, 2003), we focused here on quantity. Increasing the quantity of generated ideas by itself is a challenge for beginning engineers (Crismond & Adams, 2012), but quantity is also associated with overall idea quality (Linsey et al., 2011), and so is a key metric.

Methods

Four interventions were tested in this study: (1) *Adaptive Framing*, (2) *Innovative Framing*, (3) *Teaming*, and (4) *Tools*. The general study design was a comparison between a neutral ideation activity without any of the interventions, followed by another ideation activity with one of the interventions. Thus, there was a within-subjects comparison between the first (*Neutral*)

and second (*Intervention*) ideation activities, and a between-subjects comparison of the intervention types.

Participants

One hundred and one high school students attending an engineering-focused summer program participated. There were five sessions of students in the program, and each session was assigned to an intervention as a group. To maximize the number of two-person teams the session with the largest number of students was assigned to the *Teaming* intervention. Two other sessions were assigned to the *Tools* intervention. The remaining two sessions were assigned to the *Framing* intervention, such that each participant within that session was randomly assigned to either the *Adaptive Framing* or the *Innovative Framing* intervention. Because of the setup of the summer program, the groups were not demographically identical. The most notable difference was that the *Teaming* group was made up of students who had just completed 9th and 10th grade, whereas all the participants from the other groups had just completed 11th grade (see Table 1).

Materials

Three problem contexts and three versions of each context were developed. The versions were different framings: (a) *neutral*, (b) *adaptive* and (c) *innovative* (see Figure 2 for an example). The neutral framing was intended to allow the participant to pursue whatever ideation approach they felt was best. The two non-neutral framings were intended to encourage a solution-focused approach.

A paper-and-pencil reflection survey was designed to elicit participants' perceptions of their ideation process. The survey included forced-choice ratings and open-response items. The main item analyzed for this study asked participants, "how easy or difficult was it for you to come up with design ideas?" to assess their perception of the difficulty associated with the ideation process.

Procedure

All students from a session completed the study at the same time. The activities began with a five-minute general introduction to ideation, including three common practices: (1) generate different ideas; (2) avoid evaluating your ideas; and (3) record your ideas using drawings and text. We were careful not to bias their process toward a particular ideation method. Participants were then provided with a problem description and idea sheets to record their ideas. Participants were instructed to record one solution idea per idea sheet. They were given twenty minutes to generate ideas individually. After the ideation activity, participants were given ten minutes to complete the reflection survey.

The participants then did a second ideation activity. The problem contexts were counter-balanced such that no participant generated ideas for the same context more than once. The procedure was similar to the first ideation activity except for key adaptations for each intervention. For the two *Framing* interventions, participants were simply told that this would be a second opportunity to do ideation in a new problem context. Participants assigned to the *Adaptive Framing* intervention were given an adaptively framed problem statement, while participants assigned to the *Innovative Framing* intervention were given an innovatively framed problem statement. For the *Teaming* intervention, participants were instructed to work together as a team with the person sitting next to them, to work collaboratively for the entire duration of the activity, and to attend positively to each other's ideas. They were also instructed to record their ideas individually, so each individual was free to record (or not) whichever team or

individual ideas they felt were appropriate. For the *Tools* intervention, participants were provided with ten *Design Heuristics* cards and were instructed to use the cards to help generate ideas. Finally, participants in all the interventions completed the second reflection survey individually.

Results

Number of Ideas Generated

Descriptive data on the number of generated ideas are reported in Table 2. The data were analyzed using a repeated measures ANOVA with the number of generated ideas as the dependent measure. Ideation activity (*Neutral* or *Intervention*) was a within-subjects factor and intervention type (*Adaptive Framing*, *Innovative Framing*, *Teaming*, or *Tools*) was a between-subjects factor. The ANOVA results showed a significant main effect of intervention type, $F(3,97) = 2.91$, $p = 0.04$, but no significant main effect of ideation activity, $F(1,97) = 1.03$, $p = 0.31$, and no significant interaction between ideation activity and intervention type, $F(3,97) = 1.93$, $p = 0.13$. This indicates that overall the number of ideas generated was different among the intervention types. However, there was not evidence to suggest that there was an overall positive effect of the interventions from the neutral ideation activity to the intervention ideation activity, nor that any particular intervention had a larger impact than another (see Figure 3). A follow-up test showed that only in the *Innovation Framing* intervention was there a significant change in the number of ideas generated, $t(17) = 2.50$, $p = 0.02$.

However, one issue with these data is that the number of ideas generated doesn't appear to be equal among the interventions in the neutral ideation activity. This was surprising given that in the neutral ideation activity all participants engaged in ideation under the same conditions. Indeed, a between-subjects ANOVA on just the neutral ideation activity revealed that there was a significant effect of the intervention type on the number of ideas generated, $F(3,97) = 5.23$, $p = 0.002$. A post hoc Tukey test showed that the participants in the *Tools* intervention generated more ideas in the neutral ideation than participants in the *Adaptive Framing* ($p = 0.02$) and *Innovative Framing* ($p = 0.01$) interventions. There were no other significant differences observed between any of the other interventions, except for a marginally significant difference between the *Teaming* and *Innovative Framing* ($p = 0.10$) interventions.

Participants' Perceptions of Difficulty Generating Ideas

Examining participants' perceptions of their difficulty generating ideas provides additional information about the impact of the interventions. See Table 2 for descriptive data on this difficulty rating. A repeated measures ANOVA was conducted with the dependent measure being the 7-point Likert-scale rating from the reflection surveys. There was not a significant main effect of ideation activity, $F(1,97) = 0.64$, $p = 0.43$, of intervention type, $F(3,97) = 0.70$, $p = 0.55$, or a significant interaction between ideation activity and intervention type, $F(3,97) = 0.47$, $p = 0.71$. As a result, we cannot conclude that any of the interventions impacted the ease or difficulty of the ideation process.

Discussion

The primary purpose of this research project was to explore how different types of interventions impacted high school students' ideation, and whether they reduced fixation. This study lays the groundwork for future studies assessing and understanding different structured approaches to idea generation for beginning engineering designers. Only the *Innovation Framing* intervention seemed to positively impact the number of ideas generated, suggesting that encouraging

beginning engineers to generate very different or radical solutions to a design problem and to relax given constraints may help them to consider more ideas. However, this leaves many questions unanswered. Our future work will consider whether different interventions may impact different aspects of ideation effectiveness (Shah et al., 2003), including such measures as elaboration, variety, novelty, and quality. In addition, there may be individual factors that explain some of the variation in how participants respond to different interventions.

Two limitations of the study restricted the conclusions we were able to draw. First, because the groups generated a different mean number of ideas even in the neutral ideation activity, the groups may have differed in some aspects that we were not able to explain. Replicating the study in additional groups would help to increase the reliability and validity of the results, but additional case analyses of individuals' responses to the interventions using their reflection surveys may help identify individual characteristics that could explain those neutral ideation differences. Second, we were not able to separate the effect of the intervention compared to a practice effect. That is, what impact might we have observed if the participants were given a second neutrally-framed problem without any of the interventions? In what ways do each of the interventions impact participants' ideation over and above the practice effect? Including a control group in future studies may help tease this apart. In both cases, however, it may be possible to do further analysis with the reflection survey responses to triangulate the existing results. Our future work will focus on providing a richer picture of the impact of each intervention.

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Appendix A – Tables

Table 1: Demographic information for each intervention group.

		Gender		Race/Ethnicity			
Group	*n*	Female	Male	White or Asian	Under-represented Minority	Grade Level	Mean Age (*SD*)
Framing							
Adaptive	18	3	15	8	10	11th	16.7 (0.5)
Innovative	18	6	12	6	12	11th	16.7 (0.5)
Teaming	27	12	15	10	17	9th or 10th	15.3 (0.9)
Tools	38	13	25	17	21	11th	16.6 (0.5)

Table 2: Mean (SD) number of ideas generated and difficulty ratings by intervention.

	Adaptive Framing	Innovative Framing	Teaming	Tools
Number of Ideas				
Neutral	2.7 (1.1)	2.7 (1.1)	3.6 (1.2)	3.9 (1.5)
Intervention	2.9 (0.9)	3.4 (1.4)	3.8 (1.8)	3.7 (1.8)
Change	0.2 (1.1)	0.7 (1.2)	0.2 (1.4)	-0.2 (1.5)
Difficulty Rating				
Neutral	4.1 (1.4)	4.2 (1.9)	4.1 (1.5)	4.4 (1.7)
Intervention	3.9 (1.5)	4.8 (1.4)	4.2 (1.6)	4.5 (2.0)
Change	-0.2 (1.9)	0.6 (2.2)	0.1 (2.0)	0.2 (2.3)

Appendix B – Figures

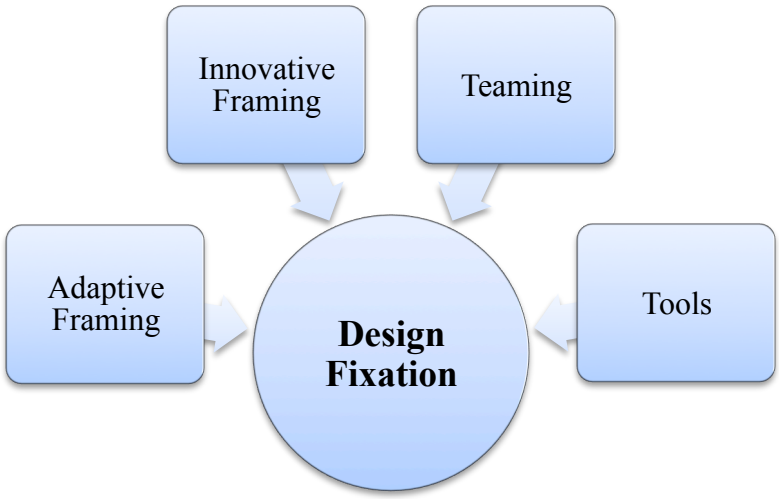

Figure 1: Diagram of the study as a focus of the impact of four interventions on design fixation.

Public Place Belongings Securer

Problem #3A

Working in coffee shops and public places has become a common occurrence. Sometimes, however, it becomes necessary to step away for short periods of time to take a phone call or use the restroom. Once a workspace has been set up, it can be very inconvenient to pack it all away for these short absences. However, there is a danger of theft when leaving items in public places.

Design a way for someone to secure several of his or her belongings in a public area to prevent theft quickly without disrupting the space.

Develop solutions for this problem. Be sure to write each solution on a different piece of paper, and use drawings to sketch your ideas. It's important that you do your best and continue working for the full time of the activity.

Public Place Belongings Securer

Problem #3B

Working in coffee shops and public places has become a common occurrence. Sometimes, however, it becomes necessary to step away for short periods of time to take a phone call or use the restroom. Once a workspace has been set up, it can be very inconvenient to pack it all away for these short absences. However, there is a danger of theft when leaving items in public places.

Design a way for someone to secure several of his or her belongings in a public area to prevent theft quickly without disrupting the space. **Your solutions should focus on improving existing designs or adapting familiar ways of approaching the problem or similar problems.** Consider constraints such as weight and size in your solutions, so users could carry it with them. Also think about how the solution would allow someone to secure several things of various sizes at one time.

Develop solutions for this problem. Focus on developing **practical** solutions. Try to develop solutions that are cost-effective and immediately workable. Be sure to write each solution on a different piece of paper, and use drawings to sketch your ideas. It's important that you do your best and continue working for the full time of the activity.

Public Place Belongings Securer

Problem #3C

Working in coffee shops and public places has become a common occurrence. Sometimes, however, it becomes necessary to step away for short periods of time to take a phone call or use the restroom. Once a workspace has been set up, it can be very inconvenient to pack it all away for these short absences. However, there is a danger of theft when leaving items in public places.

Design a way for someone to secure several of his or her belongings in a public area to prevent theft quickly without disrupting the space. **Your solutions should focus on creating totally new designs or developing totally new ways of approaching the problem.** Don't be concerned about a particular size or weight of your solution, and feel free to choose any materials you desire, as those sorts of constraints might be able to be worked out in the future.

Develop solutions for this problem. Focus on developing **radical** solutions. Try to develop solutions without concern for cost or immediate workability. Be sure to write each solution on a different piece of paper, and use drawings to sketch your ideas. It's important that you do your best and continue working for the full time of the activity.

Figure 2: An example problem description in a Neutral (top), Adaptive (middle), and Innovative (bottom) framing.

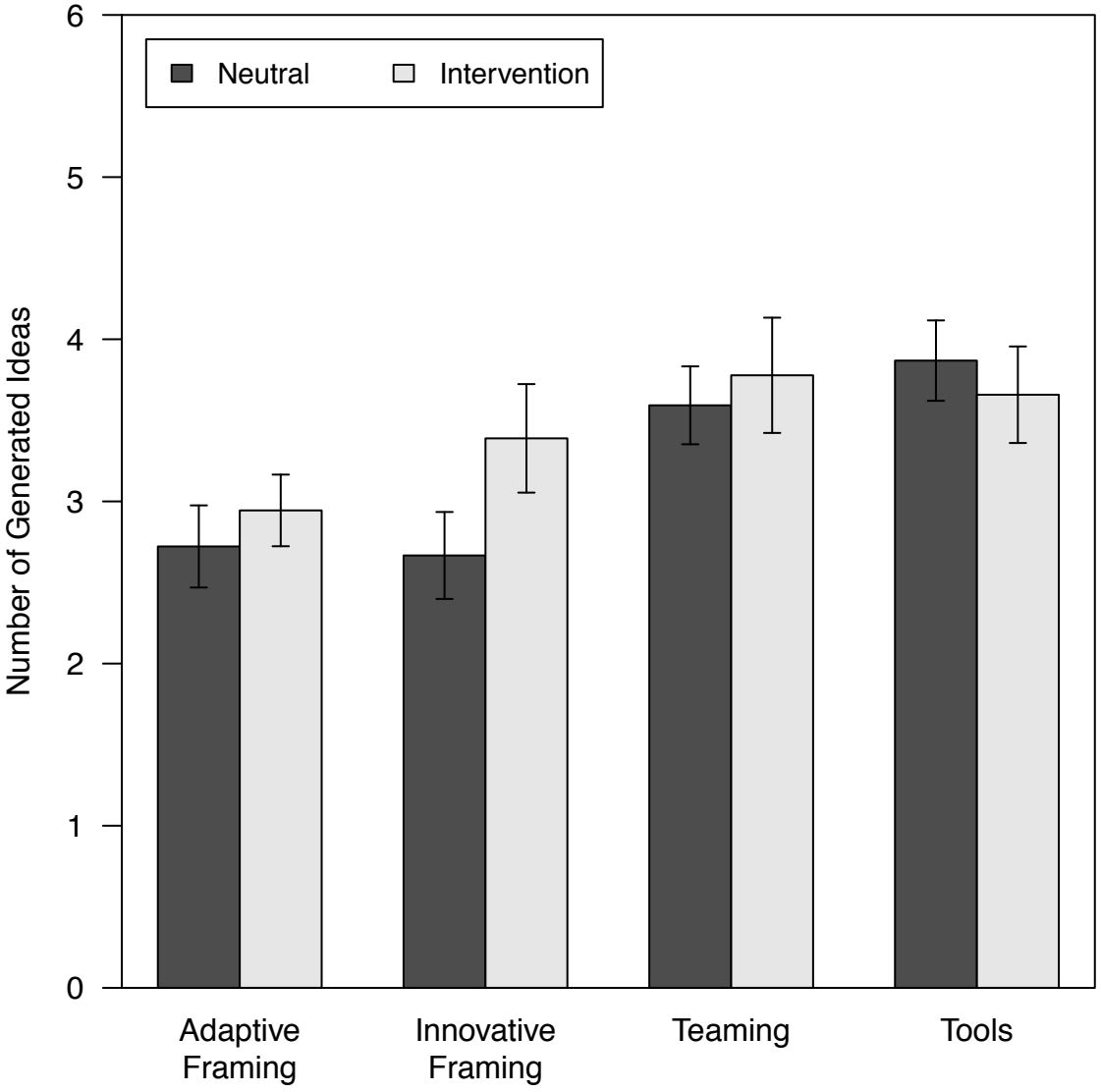

Figure 3: Mean number of ideas generated (+SE) by intervention.

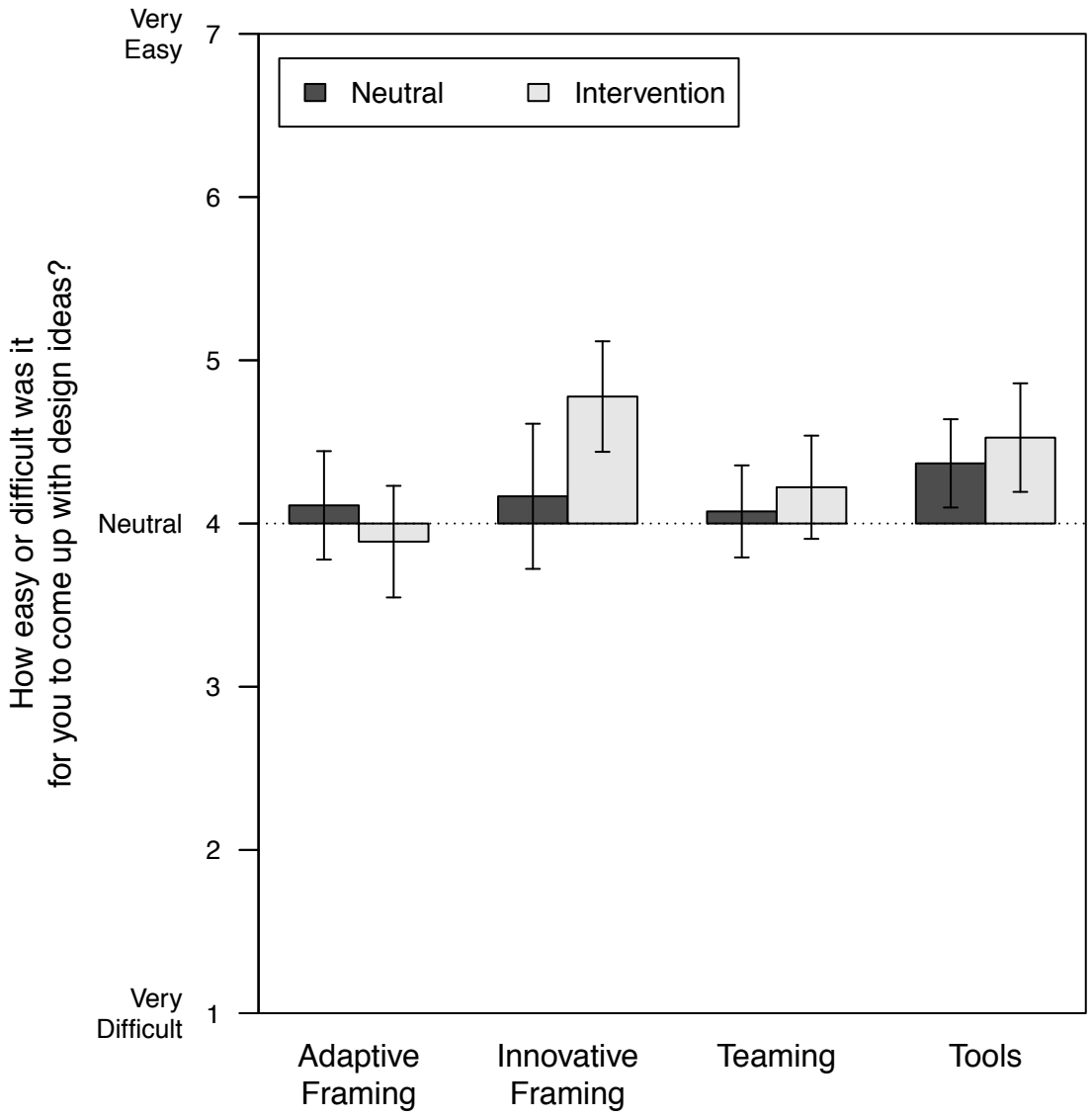

Figure 4: Mean difficulty ratings (+SE) by intervention.