The psychological experience of prototyping

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While scholars have studied what design practices accomplish, few have considered how people feel when enacting these practices. An eighteen-month ethnographic study of a high-tech firm examined the psychological experience of engaging in the practice of low-fidelity prototyping. The study finds that the production and rapid visualization of multiple ideas through low-fidelity prototyping allows practitioners to reframe failure as an opportunity for learning, supports a sense of forward progress, and strengthens beliefs about creative ability. Results suggest how design work practices can be designed to help employees manage in uncertain conditions.

Keywords: psychology of design, design management, design practice, design cognition, job design

Grace, a member of a design team at Big Tech, was initially overwhelmed by the complexity of her new assignment to create an online community and concerned about not making progress. As she described her idea to her colleagues, she struggled to communicate her ideas about all of the components of the site. She grabbed a pile of paper and began to prototype the site's layout. With her low-fidelity prototype, or a minimally detailed physical manifestation of her idea, Sally, the knowledge management team lead, quickly engaged in the conversation and suggested asking a company developer to mock up a digital, interactive version of the website. Grace commented, "I had a whole bunch of sketches that I gave to him [the developer]. And over the New Year's weekend we essentially designed the thing and implemented it. So I still owe him. [She laughs.] But it was like, you know, 'Here's the goal. Here's some sketches'…And by January, we actually had a system." During an interview, Grace described how the rapid creation of a low-fidelity prototype, rather a time-intensive high-fidelity prototype online, accelerated the project's development. She described how low-fidelity prototyping was a useful tool in effectively communicating ideas and contributed to her sense of making forward progress.

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This vignette, captured during ethnographic observations of a design team, illustrates the low-fidelity prototyping practice of making quick, minimally detailed visual representations of ideas, and how this practice influences both what work is accomplished and how the worker feels about his or her work. Understanding what work is accomplished and how workers feel about the work is critical for organizations that rely on motivated and satisfied workers to complete the work outcomes necessary for success (Hackman & Oldman, 1975, 1980).

While scholars have studied what work is accomplished when people engage in popular design practices such as user observation (Ball & Ormerod, 2000; Button, 2000), brainstorming (Diehl & Stroebe, 1987; Paulus, 2000), sketching (Purcell & Gero, 1998; Suwa & Tversky, 1997; Yang, 2005) design documentation (Dong, 2005), and prototyping (Dow, Heddleston, & Klemmer, 2009; Houde & Hill, 1997; Yang, 2005) few scholars have considered how people feel when engaging in these popular design practices. Even fewer have investigated how people feel when engaged in design practices in a work context, as opposed to a laboratory study. This paper explores the experiences of a thirty-five member team at a large high-tech firm as they used the low-fidelity prototyping practice to design and develop globally-distributed digital products.

1 *Theoretical framework*

Design is a learning process (Beckman & Barry, 2007; Fong, 2003; Owen, 1998). People construct new knowledge through observations that yield insights; insights support frameworks that inspire ideas that lead to innovative solutions (Beckman & Barry, 2007). Through this process, people construct knowledge (Dong, 2005), moving back and forth from the analytic phase of design, which focuses on finding and discovery, to the synthetic phase, which focuses on invention and making (Owen, 1998). Building on Kolb's experiential learning theory, Beckman and Barry (2007) describe knowledge creation through the design process as movement between concrete experiences and abstract conceptualization, reflective observation, and active experimentation. Kolb's experiential learning theory (1984) focuses on how knowledge is created by transforming experiences - when a person carries out a particular action in a particular setting, reflects on the effects of that action, attempts to understand those effects, and then modifies actions to accommodate new ideas. Inductive and deductive practices support the construction of new knowledge that designers use to shape the environment in ways that did not previously exist.

Although researchers describe how design work practices support the construction of new knowledge, few studies consider how people psychologically experience the construction of knowledge while enacting design work practices.

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When people construct new knowledge, they initially experience uncertainty, or a state of being in doubt, because the final outcomes are not yet known (March, 1991). The experience of uncertainty is mediated by perceptions of control and fear of failure. Peoples' experience of uncertainty depends on their perception of their ability to control the uncertain conditions (Bandura, 1997). In uncertain conditions which promote high control, individuals experience increased intrinsic motivation, greater interest, less pressure and tension, more creativity, more cognitive flexibility, better conceptual learning, higher self-esteem, more trust, and greater persistence (Deci & Ryan, 1987; Seligman, 1990). In these environments, they are more likely to be proactive and take action in the face of setbacks (Seligman, 1990). In contrast, in uncertain environments that promote low control, they are less likely to experience these positive outcomes and engage in productive creative work in the face of setbacks (Taylor & Brown, 1988).

Perceptions of ability to control are developed through mastery experiences (Bandura, 1997). Individuals who are persuaded of their ability are more likely to put forth greater effort and commitment to a given task than they are to self-doubt. Further, timing matters. Giving and communicating confidence in the early stages of skill development makes a notable impact on the development of perceived control because individuals can easily credit themselves for the positive effect immediately after the action has been taken (Schunk, 1984). Fear of failure reduces overtime, allowing individuals to take on more ambitious challenges (Bandura, 1997).

Individuals are more likely to experience mastery experiences when large tasks are broken down into moderate size tasks (Weick, 1984). By breaking a large problem into smaller tasks, individuals perceive existing skills as sufficient to deal with the demands of the small pieces. Rewards for each success are considerable, yet the cost of failure is perceived as small (Weick, 1984). Individuals are more likely to put forth greater effort and commitment to a given task than they are to self-doubt (Bandura, 1997). Individuals expend additional effort to appear consistent with previous efforts, committing themselves to a set of practices (Cialdini, 2001). Further, individuals are prone to adopt beliefs and practices that provide an increased sense of control (Gilovich, 1991).

Design scholars find that designers embrace the uncertainty to create new solutions not yet identified by others (Cross, 2002), but what they do to embrace the uncertainty is not clear. More recently, researchers propose that designers adopt design practices such as low-fidelity prototyping to promote control in the face of uncertainty (Gerber, 2009). When prototyping, practitioners break larger tasks into modest size tasks, allowing them to take frequent action. By taking frequent action on manageable tasks, practitioners experience small wins by observing their impact and attributing success to their actions. This

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paper similarly employs a psychological lens to explore how practitioners experience low-fidelity prototyping.

Low-fidelity prototyping, or the making of physical or virtual representations of ideas, is a critical practice for design practitioners used to construct knowledge about a design, communicate ideas and make decisions (Kelley, 2001, 2005; Schrage, 1999; Wall, Ulrich, & Flowers, 1992). The use of low-fidelity prototyping is well established in user interface design as a method for gathering useful usability data at a low cost (Sefelin, Tscheligi, & Giller, 2003; Walker, Takayama, & Landay, 2002). Designers use low-fidelity prototypes as a low cost way of thinking (Walker et al., 2002), refining a design earlier in the process than would be possible if designers could only test one fully developed prototypes. By testing several low-fidelity prototypes, designers obtain more critical comments that help to identify problems throughout the design process (Tohidi, Buxton, Baecker, & Sellen, 2006). In this way, designers construct new knowledge quickly by showing prototypes to stakeholders rather than spending time in isolation building elaborate prototypes that may or may not suit the stakeholders' needs or work in the way in which they were intended (Floyd, 1984). For example, when designing a user interface for a new website, a designer might create multiple low-fidelity prototypes by mocking up a wireframe model in a visual graphics program such as Adobe Photoshop. Each interface may take less than one hour to create and does not fully function, but merely represent what an interface may look like. Unlike high-fidelity prototypes, low-fidelity prototypes are not mistaken for a final design (Walker et al., 2002). Collectively, this research focuses on how low-fidelity prototyping impacts product development.

This paper focuses on the psychological experience of low-fidelity prototyping from the practitioner point of view, rather than on the well-established outcomes of the practice such as time, effort, cost savings, and idea sharing with stakeholders involved in the design process (Yang, 2005). The exploratory study reveals that enacting low-fidelity prototyping allows practitioners to reframe failure as acceptable and necessary, rather than something to be avoided, supports a sense of progress, and strengthens beliefs about creative ability. As such, this design practice helps practitioners to persist in the face of uncertainty.

2 Research approach

2.1 Methodology

The findings presented in this paper are grounded in an eighteen-month ethnographic study of a thirty-five member team, the Green Team, in a large technology firm, "Big Tech" as they enacted the user-centered design process. The advantage of this research approach is the ability to collect real-time longitudinal data about the experience of enacting the process rather than

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retrospective reflections; the disadvantage is that biased is introduced through participant observation (Spradley, 1980). The Green Team invited the researcher from a local university to objectively observe the team's development. Upon arrival, the researcher explained her ethnographic research methodology to the team. She explained that her observation and interview notes would not be shared with anyone, that she was not a paid consultant or evaluator, and that she would conclude her eighteen-month observation with a verbal report of the steps taken to develop the team. No informants names, titles, or positions would be revealed. The researcher reiterated her commitment to objective recording and anonymity throughout the eighteen-month period.

2.2 Site

Big Tech's product development efforts are multi-national and the firm's products and services are sold throughout the developed world to over 90,000 customers in 120 different countries. The company's stock is publicly traded and, throughout its history, it has been considered financially successful. The company employs more than 25,000 employees. While the majority of the company is located in Europe at Big Tech's headquarters, they have offices located in the United States. The study took place in Big Tech's United States' location, and focused on the adoption and use of a user-centered design process that emphasized the use of low-fidelity prototyping as a way of quickly realizing ideas and testing them with users.

2.3 Data collection

As is typical with grounded theory, this study was initiated with open qualitative data collection, rather than specific hypotheses about what was to be found so as not to unnecessarily constrain the emergent framework by precisely identifying and operationalizing variables before data collection began (Glaser & Strauss, 1967). The study was framed with a broad research question: How does a new design team form and adopt and implement a user-centered design process?

During the first three months, the corporate strategy team recruited and trained members for the Green Team, which was formed in response to senior management concerns about product usability and development time. The strategy team retained a design consultancy firm specializing in design processes to teach the user-centered design process through collaborative project work. Learning through project-based work differed from traditional management consulting firm engagements where consultants either present Power Point decks on process or manage work independently, both of which result in the client being less actively involved in learning new skills.

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After this initial three-month trial and training period, Big Tech's board officially approved the creation of the Green Team. The team's goal was to accelerate the adoption and use of a user-centered design process to generate user-friendly and innovative products, processes, and services to positively impact the company's revenue. The remaining fifteen months were spent observing the formation of the thirty-five member team, project selection and completion, and the coaching of human centered design in internal teams.

Data collection can be divided into six categories: observations of meetings, observations of strategic off-sites, observation of client service engagements, semi-structured interviews, collection of team-generated materials, and collection of externally-generated materials. Team materials were collected throughout the eighteen-month period and included items such as power point decks and process manuals. Data collection consisted of 360 h observing the day-to-day activity of the team, 64 h observing strategy meetings, 20 h observing client service engagements, and 40 h of in-depth interviews with 18 members of the team who extensively enacted the user-centered design process including design researchers, user interface designers, and project managers. Data was gathered from multiple sources to have multiple measures of the same phenomenon, thereby avoiding the potential problem of construct validity within a single case (Yin, 1994).

Verbatim transcriptions were made for all observations. The researcher took notes in short-hand of all observable activities (verbal transactions and behaviors) and time-stamped her notes every 15 min. An audio recording captured semi-structured interviews and transcriptions were made within 24 h of the interviews. The researcher was invited to all meetings except for one regarding financial compensations for the team. Because the researcher started her observations before the team officially began and before the majority of the team members were invited to join the team, when new members joined the team, the researcher was introduced as though she were a member of the team - but with a unique position as the "researcher". For this reason, the team did not react to such close observation and monitoring. The researcher introduced herself to each new member of the team as he or she was hired and offered to answer any questions.

2.4 Data analysis

Following guidelines for inductive research (Strauss & Corbin, 1990), descriptive accounts of observations were read and re-read until major themes emerged. Phenomena were clustered into larger conceptual categories. Simultaneously, pertinent literature was researched to understand existing theory and to uncover related phenomena. Initial data analysis began after twelve months of observation so that the remaining six months of ethnographic study could be used to gather data pertaining to emergent themes.

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Moving between inductive and deductive thinking, a conceptual framework emerged linking the low-fidelity prototyping practice to the observed phenomena. This iterative process allowed for the development of initial inferences about the psychological experience of enacting the low-fidelity work practice. The theory was validated against the data by reviewing all relevant data and compiling evidence and evaluating the strength of my evidence to inform whether inferences should be modified or abandoned based on insubstantial evidence. Following Strauss and Corbin's (1990) guidelines, an evidence-supported theory of how people experience control in the face of uncertainty through the enactment of the low-fidelity prototyping practice was developed.

After initial data collection, patterns emerged. The most interesting and promising patterns were pursued (Mintzberg, 1979). Data was collected from the time the team was introduced to the design process, and continued through application of the process to over fifteen digital products and services. This data informed inferences about the practitioner's experience of low-fidelity prototyping. Primarily, case studies are conducted retroactively, relying on reflection. The advantage to this research approach is the ability to collect real-time longitudinal data; the disadvantage is that bias is introduced through participant observation (Spradley, 1980).

3 *Findings*

This section of the paper consists of thematic-based vignettes that describe the nature of the low-fidelity prototyping practice at Big Tech, which offer insights into how practitioners relied on low-fidelity prototyping to manage the uncertainty inherent in knowledge creation in the design process. The vignettes illustrate not only the impact of the low-fidelity prototyping practice on work outcomes, but also the psychological impact for individuals and groups engaged in the practice.

The findings are organized according to three key psychological themes. Engaging in the practice of low-fidelity prototyping: 1. reframes failure as an opportunity for learning 2. supports a sense of forward progress, and 3. strengthens beliefs about creative ability.

3.1 *Reframes failure as opportunity for learning*

Rapid prototyping supports the production of many ideas, thereby minimizing the importance of any single idea, and sets an expectation that failure is an acceptable part of the product development process.

A burgeoning belief in the value of generating large quantities of ideas and minimizing the importance of any single idea became evident during the "100 Interfaces in 100 Days" design challenge, a highly generative project that was led by The Green Team.

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After being charged by Jim, an executive vice president of sales, to build a new interface for one of their most popular products in 3 months, the team decided to engage developers throughout the company in rapid-prototyping workshops to deliver as many interfaces as possible. They created the "100 Interfaces in 100 Days" design challenge. The team made this goal concrete and set an expectation that the developers would meet it. They invited the developers to two-hour workshops held approximately once a week throughout the 100 days and challenged them to make a prototype in that time. (Typically, developers would spend at least two weeks creating a basic prototype.)

The low-fidelity prototyping process encouraged developers to focus on creating a large number of wire-frame interfaces rather than one perfect interface. This had a powerful impact on how the developers worked and focused attention on idea generation rather than idea perfection.

At the end of the workshops, the developers reported great satisfaction in having created prototypes that, while not perfect, communicated their general concept. The head of the Green Team acknowledged after the 100-day period that many of the prototypes developed were quite weak, yet they revealed in a concrete way what would not work. He described failures as a way of learning and was very excited and satisfied by having reached their numerical goal and exposed developers to the practice of rapid-prototyping.

In a weekly meeting to update his colleagues about the challenge, Martin, the project lead, described his satisfaction in showing the large number of prototypes to the executive vice president who credited the team for generating so many ideas. Even though there were concerns about the quality of many of the ideas, the team was hopeful that some could be developed into quality prototypes. This tacit approval of the rapid low-fidelity prototyping practice at the executive level was vitally important, and led to a developing belief that failed attempts were acceptable and even necessary as a way to learn what did not work within a larger goal of developing a product.

In addition, the prototyping practice impacted those in charge of the workshops. In a weekly team meeting, team members George and Mary described the way the rapid low-fidelity prototyping practice was enacted in different locations.

George stated, "They [the developers] were able to walk away with paper prototypes. They had models they could work from right away. So as a result of that success on Tuesday, we are going to do another session [next] Tuesday for the US environment… We will set up the solution center like a mini-war room. We will have technical support from Jenny's team as well as UI support from our team.

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Mary described how "….we were able to offer four hours of office hours here in Lyon and were able to improve designs on the fly. This model worked well."

Enacting rapid low-fidelity prototyping sets an expectation that failure is acceptable and necessary part of the product development process. As evidenced in the "100 Ideas in 100 Days Challenge", the pressure to produce the perfect prototype was reduced by the sheer number that was expected be produced and "failures" revealed what would not work.

Rapid low-fidelity prototyping also prevented participants from ruminating about not getting the solution "right". This became evident when Alice, a programmer, expressed concern about her idea because she wasn't sure if it was fully developed.

> "I am hesitant to start talking to people about this."

Len, the Green Team manager smiled, and reminded Alice of guidelines of the rapid low-fidelity prototyping practice that encouraged the production of many prototypes "as a way of thinking through problems" and deferring judgment of early prototypes initially.

Alice replied, "We can do that. We can still talk but just be really casual about it."

Soon after this engagement, Len wrote notes on his ideas regarding the value of rapid-prototyping and distributed them to his team.

> "Failure is the key to success if an iterative approach is used for design. Each failure should lead to insight into the reasons for that failure and lessons to improve the design. If one follows this premise, then the more that a designer fails, the better the design eventually becomes. A designer that can prototype most quickly and cost effectively can iterate (and fail) most frequently and gain a high degree of confidence in the final design."

Len's memo was subsequently discussed at team meetings. Team members agreed that experiencing the successes and failures of iteration was key to navigating the uncertainty of the development process and what ultimately supported the team's success and their confidence in the final design.

These examples illustrate how the rapid low-fidelity prototyping mindset was becoming a part of the working culture in the organization. The Green Team employed low-fidelity prototyping as a way to quickly communicate their ideas and build new ideas together, thereby strengthening group efficacy, or the belief in the group's ability to successfully complete a task (Lindsley, Brass, & Thomas, 1995). Increased feelings of ability influences what goals people set, how much effort is expended, perception of difficulty of engaging

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in tasks, persistence, and attribution and resilience to failure (Bandura, 1997; Deci & Ryan, 1985; Schunk, 1984).

3.2 Fosters a sense of forward progress

Engaging in prototyping enabled the Green Team to see forward progress in an illustrated innovation process in a short time. Progress was measured by shortening a product development timeline, which seemed to give the them a sense of accomplishment as they worked.

John, the Green Team manager, described the central role of prototyping at the end of a project focused on the development of an online tool. The project was developed in six months, rather than a more typical two-year time frame. The team was praised for this.

> "What the [Green Team] does is prototyping, rapid prototyping…we didn't have our own developers yet, so we found a couple guys in marketing that were really passionate about it, [and they asked] 'Hey, can we help you? We can do Flash and HTML.' We put together a prototype that has had showing, story-telling part and at the same time we were getting feedback from the people who went through the prototype, so it's kind of two panels… we had some tailored questions like, 'Do you think it's painful, you know, or do you have a camera with a mobile phone with a camera?' And so on. And people would respond to that as well. So, we sent it to the same consultants and got huge praise, you know, 'That's what we want to do. And then, we started working with solution management and actually got some of these things into the product.' We did it in a mini-cycle that usually, you know, takes years for [Big Tech.]"

In a conversation with the vice president, John attributed the Green Team's quick development time to their practice of low-fidelity prototyping saying, "It was a pillar of the team's process."

Based on the success of the project, the Green Team eagerly asked the vice-president if they could work on two more high profile projects with the expectation that they would complete it in a shortened amount of time. They reported relying on the process of low-fidelity prototyping to develop a viable solution in a short amount of time, and described the process in a positive light. John described the situation

> "…we were figuring it out…what we did for_[the first project] is something that [Big Tech] needs on a grander scale…We would bring in our user-centered design approach for industries that Big Tech had a big interest in…we wanted to do something that was really pushing our product forward…In mid-August, we started with the so-called Alpha Project, We knew that, this [user -centered design process] is a great thing. This is something that can turn into something much bigger…"

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This example highlights how the low-fidelity prototyping practice was considered a critical tool for the team's success because the team felt they were making progress at a faster rate than the typical Big Tech development process. This fostered a sense of accomplishment within the team.

Low-fidelity prototyping also supported rapid feedback cycles in which both designers and clients gained rapid insights. Jane, a designer, described how she developed rapid prototypes to show to a manager who was skeptical about the project.

> "I think he's just like…this is impossible. He said something like, it takes one year or two years to just let them to agree on something. So, he just sees this as … a roadblock for him to get things done… So, when we sense that, we just, we change it. So, our approach is we throw the concept to him and we know he's, just see what triggers him, what makes him jump; and if it is, we'll just modify it, we don't need to, we don't want to fight for the UI's, we want to get the work done, too. I think there is flexibility in design to make things work. It's very easy to just confirm if this is working. Or let them see our design and let them comment on it, and if this doesn't work, we can just create another scenario."

Jane described how, because he had several prototypes, the manager showed it to users and in doing so, gained confidence that the project was making progress.

> "And he actually showed this prototype to customers and then back to the developers and the developers saw this and they said they're going to change their customer leader sheet based on our [work]. If he can't beat others using this process [low-fidelity prototyping], he will not use this process."

Consistent with previous research on work outcomes associated with prototyping (Houde & Hill, 1997), this study finds that low-fidelity prototyping provides a means to quickly and effectively communicate ideas. The quick and effective communication of ideas energized the team as it moved forward.

Green Team project leaders often promoted the benefits of low-fidelity prototyping as a means to quickly and effectively communicate ideas with others, giving superiors the impression that progress was being made. Anne, a project lead for a high-profile tool for large businesses, insisted that her team begin with low-fidelity prototyping rather than talking about potential ideas as a way to communicate to others that they were making progress.

> "I mean in the end, the user tells us what is the most important to them. If anything we should focus on what is most important to them. Our boss keeps telling us to get moving already. We don't want to get to the end of the year and see that we have done nothing."

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At other times, low-fidelity prototyping was used to communicate a new idea with web developers and answer unanswered questions. Joan, a design researcher, describes how low-fidelity prototyping supported her ability communicate new ideas to an international team of developers.

> "The intention was to do a wave [of prototypes] each month, so what we did was we had a html prototype and I worked together with the designer. What I learned was she was really fragmented and she ended up hiring a designer who wasn't aware of any of this back story, and so I ended up editing the html prototype too over time. But what worked about that was I would take that prototype, go and talk to people, and then update it, and then development would use that as a living spec. So every time we learned things, they were referring to the latest, greatest. So, we really did do some iteration there."

These examples highlight how low-fidelity prototyping fosters quick communication about outstanding questions. When these questions are answered, decisions about the products' development are made, and this supports forward progress.

3.3 Strengthens beliefs about creative ability

The Green Team employed low-fidelity prototyping as a way to quickly communicate their ideas and build new ideas together, thereby strengthening group efficacy, or the belief in the group's ability to successfully complete a task (Lindsley et al., 1995). Increased feelings of ability influences what goals people set, how much effort is expended, perception of difficulty of engaging in tasks, persistence, and attribution and resilience to failure (Bandura, 1997; Deci & Ryan, 1985; Schunk, 1984).

The Green Team's perception of their team's ability to be creative became evident at an offsite meeting where the Green Team gathered together to generate ideas and prototype ways in which their team could positively impact the success of the company. After filling five pieces of large paper with ideas, thus providing a shared visible construct, they began to prototype new organizational structures that they thought would allow them to have greater impact. Pens and paper were used to create the prototypes. Throughout the process, they encouraged each other to express as many ideas as possible. The visualization of multiple possibilities impacted the ways they thought of their ability to generate ideas and the pressure to generate perfectly formulated prototypes was reduced. The team generated and built so many ideas and decided, as a group, that they couldn't possibly pursue them all. And yet, in response to the activity, one team member noted, "I think we really are only using the tip of the iceberg." Another participant remarked, "Building on each other's ideas produces the best ideas." By using low-fidelity prototyping, it became evident to the team that they could produce a monumental amount of ideas. This led them to the realization that they could, in fact, enact change. Rather than

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focus on all of the things about the organization that were unchangeable, the prototyping practice focused the team's attention on all of the actions that they were able to take to change the organization. This realization strengthened the group's creative efficacy.

In another instance, a designer described how the prototypes the team created helped to focus the team and remind them of their potential to develop the product despite organizational difficulties.

> "The technology changed, I think, four different times. The management changed. The designer went out on maternity leave. The development team changed. We had people in four different countries…we had people in Montreal, here, China, India. And what worked was we had this concept that, you know, the prototype… they could still say, "Okay, here's what we're going for," and you know what, in all honesty we achieved 15 or 30 percent. So after each thing, we kind of went back and said, "Okay, here's what happened but here's where we are. So with each technology change, don't forget, here's the user experience we're trying to go for. Yeah, so I think it was much more complicated than any other project we've done….The development team changed. The designer went out on maternity leave and I was able to pull the development lead over to my desk and actually show him the prototype. And the things that I've learned since then that should be changed to give him a sense of what we're going for."

These examples illustrate the ways in which the team used low-fidelity prototyping to develop their ideas and how this practice strengthened group efficacy.

The use of low-fidelity prototyping supports the creation of residual artifacts that serve as reminders of individual self-efficacy, or beliefs in one's ability to accomplish a task (Bandura, 1997), in times of self-doubt. Green team members strengthened beliefs in their ability to design new products for Big Tech by creating paper prototypes to communicate new ideas. In a discussion about designing a community of senior engineers to exchange ideas, Joan, a design researcher, described her idea of making a website that would allow engineers to realize the overlapping projects on which they had worked. As she described her idea, she drew a picture in her notebook of the layout of the web page. After she presented this drawing, a rapid prototype, to her co-worker Ray, he suggested they show the developer who could mock up a digital, interactive version of the prototype. Both Joan and Ray envisioned the idea existing in the future once they created the initial physical artifact. Joan subsequently described how she was working on drawing pictures of her ideas more frequently in her notebook so as to better communicate with others and push her ideas more quickly along. When struggling with a new project, she referred to these drawings to remind her of her ability to positively influence product

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development at Big Tech. Grace's colleague, Sean, who sat next to Grace, similarly displayed prototypes of past projects on his cubicle wall space to remind himself of his ability to enact change even in a large bureaucratic organization such as Big Tech.

Green Team members resisted throwing away prototypes stored in the team conference room because they reported enjoying seeing them when they met for their weekly meeting with the team. Many prototypes were stuffed into a storage cabinet and although the manager complained about their lack of space for new projects, the team members were hesitant to throw the low-fidelity prototypes away.

This example illustrates the impact of the practice of low-fidelity prototyping on individual beliefs about ability. Prototypes served as physical manifestations of ideas as well as records of past successes.

3.4 Summary

This section provides initial evidence of the psychological experience of low-fidelity prototyping. When practitioners engaged in this practice, they were able to reframe failure as learning, feel a sense of progress, and strengthen beliefs about creative ability. Yet, in all research there are deviant cases when low-fidelity prototyping initially had negative effects. This occurred most often in the initial implementation of the process as informants did experienced a sense of failure, felt frustrated by a lack of progress, and lacking a sense of belief in creative abilities. For example, when Greg, a design researcher presented prototypes of a new software interface to five senior executives and future users of the software, each executive had a different preference and opinions. Initially, Greg reported feeling stuck and confused about the future direction of the project as each person reported a different opinion. As he spoke with more people, common themes emerged and the future steps for his work became clearer. In this way, low-fidelity prototyping supported a sense of progress but this only occurred over time. In another example, at a design workshop, when first learning about rapid prototyping, a workshop participant reported feeling unsure of his creative ability as he watched his colleagues generate many prototypes. The process of rapidly creating prototypes in a group setting made him question his ability. After a warm-up period, Dan, the developer, was soon generating prototypes at the same rate as his peers.

4 Discussion

The findings from this research study suggest that when practitioners engage in the low-fidelity prototyping practice, they experience the following psychological outcomes: reframing failure as an opportunity for learning, fostering a sense of forward progress, and strengthening beliefs about creative ability. The significance of this research study is that it reveals not only what work is accomplished, but how workers feel when engaged in this practice.

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When engaged in low-fidelity prototyping, people are able to manage uncertainty as they create knowledge and shape the environment in new ways. When engaged in low-fidelity prototyping activity, practitioners quickly break large tasks into modest size tasks. By completing these modest size tasks, they produce visible results that are both self-validating and validated by others. As a result, practitioners experience increased confidence and motivation to act. With each modest accomplishment, individuals attribute success to their use of the low-fidelity prototyping practice. This then allows them to remain committed to the design process despite the uncertainty of the outcomes (Gerber, 2009).

The psychological lens applied in this study supports a growing stream of research that considers how people experience design work practices in context. Sutton and Hargadon (1996) examined the personal and organizational consequences of brainstorming, a process of generating ideas to solve a specific problem. In addition to the expected outcome of generating ideas, they found that brainstorming provided skill variety for workers, supported an attitude of wisdom in and outside the session, created a status auction that maintained a focus on designing products, impressed clients, and generated income. Paulus and Dzindolet (1993) examined the social influence processes in brainstorming and found that people's performance levels are strongly affected by exposure to information about the performance of others. Scholars (Verstljnen, Leeuwen, Goldschmidt, & Hennessey, 1998) examined sketching, an early stage work practice for designers focused on capturing ideas and observed the psychological experience of restructuring and combining mental processes experienced while sketching. In addition to improving design results and generating more divergent ideas, Dow and colleagues found that prototyping multiple prototypes in parallel leads increased self-efficacy beliefs (Dow, Glassco, Kass, Schwarz, & Klemmer, 2011) whereas engaging in serial critiques about prototypes often resulted in defensive postures (Dow, Glassco, Kass, Schwarz, & Klemmer, 2009).

While these study begin to examine how people psychologically experience design practices in the context of the design process, a full-cycle approach to conducting organizational psychological research of design practices is needed. Full-cycle research (Chatman & Flynn, 2005) initiates with observation of naturally occurring phenomena, followed by manipulation-based research settings. Researchers travel back and forth between observation and manipulation-based research to understand the conceptual underpinnings of the phenomenon and generalizability of the results. This approach avoids the vulnerabilities that occur from relying on a singular method.

With the increasing widespread adoption and proliferation of design practices in non-traditional organizations such as management consulting firms and educational institutions, design practices such as low-fidelity prototyping are

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under increased scrutiny by non-designers. Therefore, a more sophisticated and empirically validated explanation for why a practice works, including both anticipated and non-anticipated outcomes is needed. Design scholars need to develop a comprehensive behavioral, cognitive, and emotional framework for how design practices work. Further, this framework needs to be developed independently of the high-profile design consultancies who support the development of teams such as the Green Team. Evaluation of the practices needs to be separated from the evaluation of the consultancy brand. Not only was the Green Team learning a new practice, they were also benefitting from the investment, attention and support from the consultants which likely influenced their perceived competence. Understanding the psychological experience of one popular practice, low-fidelity prototyping, is a critical first step to developing an interdisciplinary framework of enacting design practices in a complex setting.

Over the last twenty years, creativity scholars have sought to identify and understand the individual, group, and organizational characteristics that enhance and inhibit success creativity in complex social systems (Amabile, 1996; Ford, 1996; Woodman, Sawyer, & Griffin, 1993). By studying the organizational context of creative work, their research has elucidated ways in which managers can support creative and innovative outcomes for their organizations. This study is an initial effort to understand how design practices influence work experiences and outcomes in a complex organizational setting. It is not enough to know that a design practice works, but it is also important to examine how it interacts with factors such as individual behavior, ability, personality, knowledge, group composition, characteristics, and organizational culture.

In the past design scholars have used a psychological lens to understand and explain how people's everyday behaviors and emotions influences interactions with designed objects (Norman, 1988, 2004). Applying this lens spawned the creation of new designed objects. This study similarly employs a psychological lens to understand the ways that people engage, enact, interact and create as they use low-fidelity prototyping in the design process. It is important to gain a deeper and more comprehensive understanding of how working with uncertain outcomes effects practitioners engaging in this practice. The design process requires one to stay in ambiguous spaces for extended periods of times as designers question basic assumptions about how the world around them works. Design work also requires that practitioners have a strong sense of self and group efficacy to persist through the uncertainty of the design process. These key factors are essential components that contribute to our understanding of how design is practiced and may influence how design practices enhance productive outcomes in the workplace.

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This research study suggests that while the social setting and team structure may influence the psychological experience, it alone does not provoke the psychological experience. The team was expected to adopt the user centered design process, yet expectations for psychological outcomes such as reframing failure, fostering a sense of progress and development of beliefs in creative ability were not specified. The senior management mandate was that five new products be released on the market, rather than that the team experience psychological benefits. In fact, it is possible that the pressure from management may have actually had the opposite effect – that of increased fear of failure, lack of forward progress, and insecurity about beliefs in creative ability as the team did not launch a single product on the market during the period in which they were to do so. Future empirical studies may explore the interaction effect of low-fidelity practices and the psychological states induced in the controlled laboratory studies to control for team structure and social setting.

5 *Methodological challenges*

Despite systematic guidelines for evaluating qualitative data such as how to gather, code, and analyze data, qualitative research is ill-suited for testing the reliability, validity, and generalizability of the very insights it generates (Yin, 1984). While qualitative case study research may be well-suited for building theory, it suffers from sampling error and investigator bias (Schein, 1987). Though the researcher took copious notes when present, it was impossible to capture all instances when the informants were enacting the work practices. Instead of collecting survey data from a large sample representative of all individuals enacting the HCD process, rich detailed descriptions of the experience of enacting the work practices in a select case were collected. While these rich descriptions are useful for developing interesting and detailed theory, the descriptions are inherently biased by the researcher's interpretations of the data. As much as the researcher tried to follow Glaser and Strauss' (1967) recommendations for data collection by writing down all observations as objectively as possible, the researcher unconsciously influenced the data collected by choosing to record some events and not others. Additionally, as discrete as the researcher tried to be while collecting data, her mere presence likely impacted the behavior of those observed and consequently the data that was collected. This research highlights both the benefits and drawbacks of studying work practices in organizational contexts. On the one hand, the researcher was better able to understand the interaction of the individual psychological experience, social context, structure, and work practices, but on the other hand, it was not easy to determine how to parse out the independent contributions of each variable as may be possible in laboratory studies.

6 *Implications for design management*

This research study suggests ways in which individuals can manage design work in uncertain conditions. The design process, like other innovation processes, does not systematically result in marketplace innovation, and when it

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does, this feedback comes long after the design process has been enacted. Although employees may initially be persuaded to pursue an innovation process because of successful implementation of the process in other organizations and interest in doing "something new", this motivation may not be sustainable (Abrahamson, 1996). Over time, employees may express uncertainty about the effectiveness of the innovation process if they do not benefit from the day-to-day enactment of their work practices. As first intimated by Hackman and Oldman's work on job redesign (1980), managers may actively design employee work experiences by using behavioral science theory to evoke cognitive, emotional, and behavioral reactions from employees. Low-fidelity prototyping is an important and useful work practice that delivers immediate feedback about work effort to employees who are tackling challenges with great uncertainty. Increased feedback about work increases worker satisfaction and motivation, reducing likelihood for costly worker turnover (Hackman & Oldman, 1980). Managers may adopt and design work practices, such as low-fidelity prototyping, to which employees are committed so they experience intermediate benefits before formal outcomes are realized. While adoption of such practices may initially face resistance due to barriers such as existing corporate culture or the skills of the workforce, the appeal of the psychological outcomes: reframing failure, fostering a sense of a sense of forward progress and self-efficacy are broad and may potentially mitigate resistance. More research is needed to understand the psychological experience of the practices across cultures.

7 *Conclusion*

This study is undergirded with a theoretical framework that supports the notion that design is a learning process (Beckman & Barry, 2007; Fong, 2003; Owen, 1998). People construct knowledge in varied ways as they engage in design processes. Kolb's experiential learning theory (1984) describes how knowledge is created through experiences. It is critical for both researchers and practitioners to understand how design work practices influence the enactment of design work. Although researchers describe how design work practices support the construction of new knowledge, few studies consider how people psychologically experience the construction of knowledge while enacting design work practices.

The practice of low-fidelity prototyping not only influences work outcomes, but also the way people feel about the work. This practice led to reframing failure as an opportunity for learning, fostering a sense of a sense of forward progress, and strengthening beliefs about creative ability Applying a psychological lens to work practices will continue to reveal new and more nuanced understandings of how designers work to create impactful change and drive innovation.

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