A Roadmap for Activated Motivation in HCI

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Everyday, millions of people use technologies like their fitbit, smartwatch, or smartphone for self-improvement. These devices and their associated apps have become both inexpensive and pervasive; they monitor our shopping habits, physical activity, and ecological footprint and visualize that data to help us reflect on our limitations, to set and make progress towards goals, and recognize achievements. The potential impacts of these technologies are immense; to improve our finances, to educate ourselves and develop new skills, and to improve our health and the health of our planet. However, research has cast doubt on their effectiveness [10, 23, 38, 52]. That is, people tend to lose motivation for self-improvement over time, and ultimately fail to meet their personal goals. To address these shortcomings, I will explore how we can use established theories of human motivation to develop novel technologies that motivate change, to provoke self-reflection and persistence, and to promote our health and well-being.

1 RECENT PROGRESS

Over the past seven years, I have worked to establish my research group, the HCI and Health lab, with expertise in technology design, evaluation, and Self-Determination Theory. My previous NSERC Discovery Grant focused on multi-device informatics (e.g., [36, 37, 48**?** , 49]), and understanding how information and interaction can bridge the many devices we use each day in our homes and work environment (e.g. [19–21]). In parallel, my research group has taken part in the Saskatchewan-Waterloo Games User Research NSERC CREATE, which has enabled us to develop expertise in Self-Determination Theory and technologies for self-improvement. These areas of expertise uniquely position my research group to develop novel technologies for self-improvement that deeply integrate our understanding of human motivation and well-being.

1.1 Technical Expertise and Laboratory Evaluation

My research group has developed extensive technical expertise in design, prototyping, analysis, and evaluation of software for novel devices like smartwatches and large multi-touch displays. For example, my PhD student **Krzysztof Pietroszek*** developed interaction techniques that enable people to use a smartwatch or smartphone to interact with nearby displays [35–37] — techniques that extend to augmented and virtual reality. Collaboration with Dr. Edward Lank and Dr. Keiko

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Katsuragawa in Computer Science has expanded on this work, and explored the idea of a smartwatch as a generic and universal computer input device (e.g., [24, 25, 42]).

In parallel, my group has continued its pioneering work around the collaborative and public use of large, touch-interactive displays. For example, work by **Leila Homaeian* (PhD)** has developed advanced analysis techniques for cross-device collaboration and a theoretical understanding of how subtle differences in user interface design can hinder or support collaborative activities like sharing information with team members [19–21]. This work complements other research from my group around how individuals approach large displays (**Mojgan Ghare*, MASc** [16]), how those displays should present information and create personal workspaces [C13, C19], and how to mitigate fatigue when using them for extended periods (**Zhe Liu*, MSc** [27]).

1.2 Qualitative Research and Toolkit Development

My research group has also developed expertise in the methods required to bring these technologies to fruition, including qualitative methods, evaluations in the laboratory and field, and the development of toolkits to support other researchers. These methods align with those required to perform the proposed research. For instance, we have expertise in qualitative methods to explore domain-specific uses of technology, like the use of tablets by individuals with aphasia (**Thomas Huijbregts* (BSc)** [22]), smartphone adoption in clinical contexts (**Denise Ng* (MSc)** [31]), and chronic disease management (**Marina Wada* (MSc)**).

Most recently, **Robert Gauthier* (PhD)** has developed advanced computational and visualization techniques to support qualitative analysis methods like Reflective Thematic Analysis [4]. He has developed the *Computational Thematic Analysis Toolkit* [15], an open-source graphical interface that is accessible to non-technical qualitative researchers (i.e., without programming experience), to make these techniques broadly available to the research community, and to non-technical researchers in domains like Public Health and the Social Sciences.

1.3 Designing Technologies to Motivate Self-Improvement

My lab has engaged in an ongoing program of research that examines how to effectively design, build, and deploy self-improvement technology. This program applies our expertise in technology design to domains with pressing needs like education [8, 9, 45, 46], nutrition [2, 3], and mental health [6, 7]. For instance, **Marcela Bomfim* (PhD)** showed that use of gameful techniques could be used to motivated fewer impulse purchases when grocery shopping [2, 3]. Similarly, **Tina Chan* (MSc)** used Self-Determination Theory as a design guide to motivate peer-to-peer support in Cognitive Behavioural Therapy [6, 7]. **Mila Tahai*** applied these techniques to develop an educational game for children with attention-deficit hyperactivity disorder (ADHD) [45, 46].

However, in demonstrating that potential, our work has also identified obstacles to the development of these technologies in practice. In particular, there's little guidance about when a gameful intervention will be most effective, compared to, for example, simple visualizations [2]. This realization aligns with calls-to-action in the CHI Play community to more deeply engage with Self-Determination Theory (e.g., [47]), and point to a need for deeper engagement with existing theory on motivation. Thus, to engage with existing theory, the proposed research program will perform the foundational science required to explore how Self-Determination Theory can be applied to technology design, followed by the applied science required to show its efficacy.

2 OBJECTIVES

The **long-term objective** of this research program is to *enable Human-Computer Interaction researchers and practitioners to deeply integrate the concepts of Self-Determination Theory [12, 40, 41] — an extensively validated macro-theory from psychology that describes human motivation and well-being — into the technologies we use today, and to shape the design of emerging technologies like augmented reality.*

The proposed research will be the first to demonstrate how *activated motivation* [40, 50], the use of text, images, and audio to prime individuals to be receptive, engaged, and persistent, can be used to make self-improvement technologies more effective. In particular, **three integrated short- to medium-term objectives** will establish the efficacy of activated motivation in interactive computer systems, and develop guidance for its use in practice:

(1) Identify *how* and *when* activated motivation can be integrated into technology through foundational science in interface design
(2) Demonstrate efficacy of activated motivation in practice through applied prototype development and field evaluations
(3) Create the *Activated Motivation Toolkit*, which provides guidance and working implementations of activated motivation on smartphone, smartwatch, and augmented reality interfaces.

3 LITERATURE REVIEW

Self-Determination Theory [12, 40, 41] is a decades-old, widely-validated macro-theory from psychology that describes human motivation. Generally, it defines motivation on a spectrum ranging from amotivation, or a lack of motivation, to extrinsic motivation driven by external factors like rewards, to intrinsic motivation associated with one's internal enjoyment or interest. Moreover, the theory establishes the benefits of more internal forms of motivation: individuals acting with internal forms of motivation will tend to feel more open and curious, be more persistent, and are more likely to succeed at difficult tasks [17, 40, 41]. Indeed, these concepts have been widely validated, and have been shown to provide a practical framework for technology design [28]. However, researchers have also argued that current engagement with the theory is shallow [32, 34], particularly some of the concepts described in Self-Determination Theory's 'micro-theories' [28].

Causality Orientations Theory [12, 40, 41], one such micro-theory, describes how an individual's motivation shapes their behaviour. It defines three *orientations* that individuals take on in pursuit of a goal: those with *autonomy orientation* are driven by internal factors like their own interests and opportunities for growth; those with *controlled orientation* are driven by external contingencies and power structures; and those with *impersonal orientation* are driven by the need to avoid negative consequences like performance anxiety or failure [40]. Like the benefits associated with more internal motivation, individuals who are autonomously oriented will tend to perform better, invest more effort, be more persistent, and enjoy a task more than those with controlled or impersonal orientations [30]. These traits have been found to translate to concrete outcomes like task time, effort, and performance in experimental settings [17, 50].

Critically, the psychology literature has also shown that an individual's orientation can be *primed*, through environmental messaging like text, music, or images — an effect called *activated motivation* [50]. That is, individuals can be prompted to take on an autonomy orientation for a task, and in doing so also take on its many benefits. Activated motivation has been demonstrated in experimental, short-term contexts for a wide range of activities, including education, sports training, and medicine adherence [17, 50]. However, it's not clear how priming can be implemented in the interactive computer systems people use on a daily basis for self-improvement, and so the potential benefits of activated motivation for self-improvement remain unexplored. In-line with these benefits, this research program will investigate how activated motivation can be used to promote self-improvement in interactive technologies, and provide guidance about *how* and *when* they are most effectively integrated into computer interfaces for self-improvement tasks.

4 METHODOLOGY

The proposed research will use a convergent mixed methods design [11], where qualitative and quantitative methods are jointly used to inform the design of technology. Laboratory studies, qualitative research, and field studies are intentionally scaffolded to first replicate activated motivation in contexts studied in the psychology literature and then to establish how they can be best integrated into interactive systems design. As the research program progresses from foundational, exploratory science to applied validation of prototypes newer and more elaborate contexts and technologies are introduced. Importantly, since the objective of this research is to demonstrate activated motivation within interactive technologies, and *not* long-term effectiveness as a medical intervention, evaluations will focus on short-term, in-context validation of its effects and changes in specific behaviours [26].

The proposed research program comprises three stages: first, two parallel research projects will conduct fundamental research into *how* and *when* activated motivation is best used in interactive systems; second, a series of applied field studies will be performed to show those effects in a practical setting; third, results from all stages will be disseminated through the creation of a toolkit that makes developed techniques and study materials broadly available to research and industry communities.

4.1a Comparative Laboratory Studies of Interface Elements

The literature has consistently shown that activated motivation can be demonstrated in short-term contexts ranging from 15 minutes to 1 hour (e.g., [14, 29, 33, 43, 51]). To demonstrate how these effects may be elicited by technology, participants will recruited to perform short-term goal-setting tasks where technology-based interventions will be compared to a control condition. **Han Xiao (PhD 2)** will lead this research activity, with **Master's B**, **Master's C**, and **Master's D** assisting with each study.

Research Methodology A series of comparative laboratory studies will be conducted to determine *how* activated motivation can be best implemented using common interface design elements. These studies will focus on establishing the immediate effects of activated motivation, and replicating results from psychology in an interactive context. Each study will implement established stimuli from the literature, like sentence scrambling tasks, images, and audio [50] within a digital context, and then empirically compare it to a control to establish efficacy. Stimuli will include sentence scrambling tasks, 'inoculation messages', followed by studies that investigate more subtle integration into icons and ambient audio, and gestural interaction techniques like the 'power pose' (i.e., [18]).

Gillison et al. [17] provides concrete guidance for design of future studies. Their meta-analysis found large, positive effects of activated motivation on autonomy and competence measures, particularly for individual adults. Based on a power analysis, they suggest that 24 participants are likely to be sufficient to show an effect of activated motivation with a repeated-measures design. All evaluations will be pre-registered with the Open Science Foundation, where experimental software, study materials, and de-identified data will be publicly available.

To capture potential differences in each interface design element, repeated measures designs will be used, with pre- and post- trial measures including; demographic information; domain-specific, validated scales regarding attitudes towards change like the Health Belief Model Survey [39]; validated scales for motivation, like the User Motivation Inventory [5]; outcome measures, like task performance and exerted effort; and a post-study awareness check. Previous research has indicated that gender and sex are *not* theoretically important [50], and so will not be controlled in these initial studies.

4.1b A Grounded Theory of Activated Motivation

As outlined above, while activated motivation has been demonstrated in experimental contexts (e.g., [17, 50]), it's not clear *when* priming techniques should be triggered during everyday use. Thus, this activity will identify contextual factors that influence an individual's receptivity, availability, and interest in self-improvement tasks. In particular, the grounded theory is expected to provide detailed information about the types of interface elements best targeted, as well as *when* such interventions are likely to be most effective. This activity will build on my research group's experience with qualitative research (e.g., [J1, J4, J8]), and will be used in conjunction with the laboratory studies from §4.1a to guide the development of later prototypes and evaluations.

Research Methodology Grounded Theory [44] will be used to create a 'local theory within the framework of SDT' [13, p.3933]. We will recruit a purposive sample of adults who currently use or have used self-improvement technologies, including wearables and smartphone apps. I expect to recruit a total of 20 participants, (2 device types × 10 participants) for 90-minute interviews.

4.2 Prototype Design and Empirical Field Studies

To demonstrate the effectiveness of activated motivation technologies in interactive contexts, three prototypes will be designed, developed, and evaluated. Each prototype will target distinct domains for self-improvement: financial, health, and education. Each target domain has been selected to include a variety of technologies in common use today (smart phones and watches) as well as those under active development (augmented reality), but also to scaffold from tasks that have been actively studied in the psychology literature (e.g., physical activity) to those less studied (e.g., nutrition) to show the generalizability of developed techniques.

Research Methodology Our grounded theory of activated motivation (developed in §4.1b) will be used to guide development of each prototype, alongside existing guidance like Food Literacy (e.g., [C1, C5]) and the Self-reflection inventory [1]. Prototypes will be iteratively pilot tested within my lab group and redesigned until ready for a field study, then evaluated using outcome and experience measures and compared against control conditions over a 1–3 month period, in-line with longer-term studies of activated motivation from the literature (e.g., [17, 50]). Since these evaluations will involve domains with known differences in behaviour based on gender (e.g., food purchases), gender will be a controlled variable in each evaluation.

This activity will build on my group's expertise in theory-based design, prototyping, and evaluation of such interventions in both lab and field settings (e.g., [J4, C1, C3]). As before, all evaluations will be pre-registered with the Open Science Foundation, where all prototypes, study materials, and de-identified study data will be available via a public repository.

Intended Collaboration This activity will leverage existing and ongoing relationships with research partners and domain experts, where each collaboration/prototype will be led by a PhD student. Nutrition (Food Literacy) will be explored first, in partnership with Dr. Sharon Kirkpatrick (School of Public Health Sciences), to benefit from hand-off between **PhD 3** and my graduating PhD student (**Marcela Bomfim**). Next, financial literacy will be explored in partnership with Scotiabank, supported by **PhD 2** and **Master's E**. Lastly, education will be explored through collaborations with Dr. Deltcho Valtchanov and Axonify (**PhD 3** and **Master's F**).

4.3 The Activated Motivation Toolkit

Finally, the outcomes of all of the above research will be enshrined in the initial versions (v0.1 – 1.0) of a publicly-available, open-source toolkit. The toolkit will comprise user interface elements for smartphones, smartwatch, and augmented reality applications, as well as all priming tasks and experimental software developed for the proposed research. The toolkit will be released under the MIT license, allowing for commercial and non-commercial use. The availability of the toolkit will also enable long-term replication and validation of findings. Source code will be available for both Android and iOS devices, and development of the toolkit will proceed in parallel to the above laboratory and field studies, led by **PhD 2**.

IMPACT

Some of the most pressing issues facing us today, like climate change and the improved health and well-being of all Canadians, require substantial, sustained behaviour change at scale. The proposed research will create tools for such change, through the pioneering of user interfaces for activated motivation, collection of empirical evidence for their efficacy, and creation of a publicly-available toolkit. The research will also have immediate impacts on Canadian industry; several local companies, including **Axonify** (Waterloo), **Google** (Mountainview and Waterloo), and **Desire2Learn** (Kitchener), currently develop technologies for self-improvement, and are positioned to immediately benefit from this research through deployment to commercial software. Finally, this research will train students in the design of novel technologies like wearables and augmented reality, as well as more generally in human-computer interaction, interface design and evaluation, qualitative and quantitative research methods, and information visualization, which are critical skills for industries developing information technologies, including the healthcare, fitness, education, and corporate industries.

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