Towards Designing for Everyday Embodied Remembering: Findings from a Diary Study

Nathalie Overdevest
Exertion Games Lab, Department of Human-Centred Computing, Monash University, Clayton, VIC, Australia; Materialising Memories, Faculty of Engineering Technology, University of Technology Sydney, Ultimo, NSW, Australia
nathalie.overdevest@monash.edu

Rakesh Patibanda
Exertion Games Lab, Department of Human-Centred Computing, Monash University, Melbourne, VIC, Australia; Materialising Memories, Faculty of Engineering and Information Technology, University of Technology Sydney, Sydney, NSW, Australia
rakesh.patibanda@monash.edu

Aryan Saini
Exertion Games Lab, Department of Human-Centred Computing, Monash University, Melbourne, Victoria, Australia; Materialising Memories, Faculty of Engineering and Information Technology, University of Technology Sydney, Sydney, NSW, Australia
aryan@exertiongameslab.org

Elise Van Den Hoven
Materialising Memories, Faculty of Engineering and Information Technology, University of Technology Sydney, Sydney, NSW, Australia, elise.vandenhoven@uts.edu.au; Department of Industrial Design, Eindhoven University of Technology, Eindhoven, Noord Brabant, Netherlands
e.v.d.hoven@tue.nl

Florian 'Floyd' Mueller
Exertion Games Lab, Department of Human-Centred Computing, Monash University, Melbourne, VIC, Australia
floyd@exertiongameslab.org

ABSTRACT

Our bodies play an important part in our remembering practices, for example when we can remember passwords by typing, even if we cannot verbalise them. An increasing number of technologies are being developed to support remembering. However, so far, they seem to have not taken the opportunity yet to support remembering through bodily movements. To better understand how to design for such embodied remembering, we conducted a diary study with 12 participants who recorded their embodied remembering experiences in everyday life over a three-week period. Our thematic analysis of the diaries and interviews led to the creation of a framework that helps understand embodied remembering experiences (ERXs) based on the level of skilled and conscious movements used. We describe how this ERX framework could help with the design of technologies to support embodied remembering.

DIS '23, July 10–14, 2023, Pittsburgh, PA, USA

ACM ISBN 978-1-4503-9893-0/23/07…$15.00
https://doi.org/10.1145/3563657.3595999

CCS CONCEPTS

• **Human-centered computing**; • **Human computer interaction (HCI)**;;

KEYWORDS

Embodied interaction, embodied remembering, memory technology

ACM Reference Format:
Nathalie Overdevest, Rakesh Patibanda, Aryan Saini, Elise Van Den Hoven, and Florian 'Floyd' Mueller. 2023. Towards Designing for Everyday Embodied Remembering: Findings from a Diary Study. In *Designing Interactive Systems Conference (DIS '23), July 10–14, 2023, Pittsburgh, PA, USA.* ACM, New York, NY, USA, 14 pages. https://doi.org/10.1145/3563657.3595999

1 INTRODUCTION

Embodied remembering describes all ways in which we use our body to remembering [20, 28, 41]. Examples of such embodied remembering are being able to remember a password by typing (even though one might not be able to verbalise it), or remembering the next step in a choreography by acting out preceding steps.

We note that an increasing number of technologies are being developed to support remembering (for example "Slide2Remember" [23] and many more [4, 7, 9, 11, 19, 45]). However, so far, these systems seem to have missed the opportunity to support remembering through bodily movements. This appears to be related to a limited understanding of how to design for embodied remembering. With this paper, we aim to begin closing this gap in our understanding. To achieve this, we set up a diary study to begin understanding

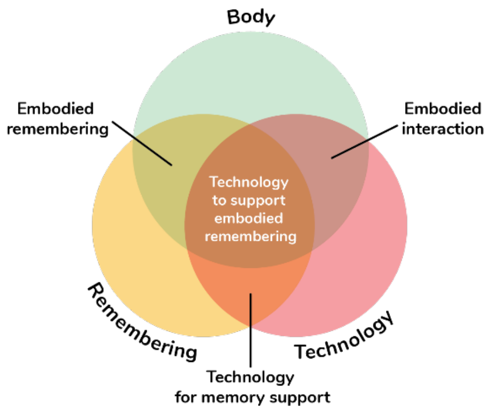

Figure 1: Venn-diagram showing how the body, technology and remembering combine to different research areas in HCI. This paper aims to improve the understanding of the centre: technology to support embodied remembering.

people's everyday use of their bodily movements for remembering to inform the design of future embodied remembering systems. Our work empirically validates and illustrates findings from existing literature on embodied remembering [6, 18, 20, 27, 32, 39, 41], while bringing it to HCI research and design. The understanding we present in this paper will hopefully be useful for designers when creating future embodied remembering systems, which in turn will benefit people looking to improve their remembering.

We present related work next and proceed by explaining our method, including the setup of the diary study, its participants and the analysis approach. Then, we follow with the results, in which we detail the reports by our participants. These results are then formulated as embodied remembering experiences (ERXs). We use these experiences to formulate an ERX framework and describe opportunities for designers aiming to create new interactive memory support systems. Finally, we discuss the limitations of our approach and avenues for future work before presenting our conclusion.

2 RELATED WORK

Our work is primarily informed by three areas of HCI research that bring together the human body, technology and remembering: embodied interaction, embodied remembering, and technology for memory support. The intersection of these three areas is our focus: technology to support embodied remembering (Figure 1). We believe that in order to understand how to design to support embodied remembering, we need to first understand how we use our bodies in traditional, non-technologically augmented, remembering. For this, we learned from prior work on embodied interaction (Section 2.1), as well as embodied remembering (Section 2.2). Then, we describe what insights we gained from existing technology to support embodied remembering (Section 2.3). Finally, we present the gap in knowledge that we have identified and the research question that aims to close this gap.

2.1 Embodied interaction

There is extensive research in HCI on technology that incorporates embodied interaction in one form or another [2, 9, 13, 17, 24]. There are different interpretations of the term 'embodied interaction', of which some are more philosophical and others more literal. Dourish describes embodied interaction *as "the creation, manipulation, and sharing of meaning through engaged interaction with artefacts"* [10, p.127]. We project our experiences and skills onto the artefact that we perceive [5], allowing us to perceive different options for action in an object [7]. Wearable computing, on the other hand, sees the body as a way to interact with technology [35], and therefore does not necessarily take all aspects of embodied experiences, such as emotions and perceptions, into account. Though Dourish' view is useful in understanding the role of embodied interaction in everyday life, but does not extend to the design of embodied interaction technologies. However, the somaesthetic design view, which has been adopted increasingly in HCI over the past years, is able to link the embodied experience as a whole with design, by taking the embodied experience as starting point for the development of meaningful interactions in technologies [16]. Looking at the different definitions of embodied interaction, our work relates more to Dourish' [10] and Höök's [16] holistic view of embodiment. We aim to support the design of technologies for embodied remembering. Therefore, the resulting technologies should allow the user to meaningfully interact with the world to support the embodied remembering process. Such interactions go beyond the wearable computing view of embodied interaction, as these should be able to fit a person's embodied remembering experience.

2.2 Embodied remembering

We learned from prior work on remembering, which often takes a psychological view of memory. This view provides a comprehensive understanding of the various forms of memory, such as sensory memory, working memory, and long-term memory [3]. However, we find that this cognitive psychological view is challenging to engage with in terms of interaction design, as it focuses on how different forms of memory function within the brain, foregoing considerations on everyday remembering practices. Embodied remembering, on the other hand, is often described through a phenomenological lens, an approach that is rooted in observations of how people remember in daily life [41]. This is based on the concept of embodiment, which describes that we engage in the world with and through our bodies, and thus experience the world through those bodies [10]. As such, embodied remembering stems from our everyday engagement with the world and the accumulated experiences, which become embedded in our bodily movements up to the point that we can act without much conscious attention [6, 32]. Prior work told us further that embodied remembering can occur because the presented stimuli carry similarity to the stimuli in the remembered event [20]. We can use our body to recall details of a particular memory by simulating parts of the memory, for example by gesturing [20, 28, 41].

Looking at the prior work on embodied remembering, it becomes clear that a full understanding is still emerging as it is a complex concept that can come in different forms [41]. These forms of embodied remembering are not strictly separated and function in a highly integrated way [41]. Nonetheless, we believe that a categorisation is useful in describing how certain experiences impact particular facets of remembering. The different forms of embodied remembering we distinguish are:

- **Embodied autobiographical memory** [41]: Describes the ways in which the body is used to remember lived-through events, either voluntarily (e.g. through simulation) [20, 28, 41], or involuntarily (e.g. by a smell or sound that activates a certain memory) [41]. Here, the body is mostly used for cognitive offloading through gesturing [18, 28], by storing information on the body (e.g. writing something on the back of one's hand) [41], by simulating the movements that one made when they experienced the event they try to remember [20, 41], or to use those gestures to communicate a memory to someone else [20, 41].
- **Social implicit memory** [39]: Or "the body memory of being with others" [6], speaking to how certain social roles require different forms of moving and behaving [6, 39]. One example is the drill sergeant who can be recognized as such outside of their work because of their "stiff gait" [39]. Transitioning between such social roles can require conscious effort, e.g. by taking time to acclimatise after work [39].
- **Embodied skills memory** [41]: Alternatively called "performance or procedural memory" [39]. Embodied skills memory refers to bodily movements that are *"embodied, culturally-embedded human routines, performances and rituals"* [41]. We perform these actions so regularly that we hardly register doing them (such as how we hold a pen), as well as the skills in which we put conscious effort to learn (such as when we first start learning to type) [39]. These actions are built up from "habitual movements" or "automation": movements that we perform so often that we do not have to think consciously about in order to execute the movement skilfully [6, 27, 32, 39, 41]. One example is cycling: avid cyclists do not have to pay conscious effort to maintain balance, which allows focusing on navigation and traffic. In fact, conscious effort appears to disrupt our ability to rely on embodied skills memory [41].
- **Implicit body memory** [39]: Refers to the *"continued experience of self"* [39]. We are not always experiencing our bodies consciously – quite often it is a "background feeling" [39]. Instead, we might not be aware that we tense our shoulders, or tap our foot. Additionally, we have a bias in how we use our bodies, which is, for example, reflected in our postural lean [39].
- **Spatial memory** [39]: Describes our embodied way to remember where we are, how we position ourselves in the world, how we get to or from that location, and our plans at that location [39]. Environments can cue embodied responses due to associated memories with that space, such as Shusterman's description of how he felt his body change as soon as he entered his old office [39]. This form of embodied remembering can be easily disrupted by a change in the physical space (e.g. when stubbing one's toe on the table that has been moved a couple of inches) [39]. Relying on our spatial memory can also result in us habitually walking to an incorrect location (e.g. to collect an item from a particular room, but one has had moved that item previously) [39].

We note that our list is not exhaustive. For example, Shusterman [39] and Casey [6] argue that "traumatic memory" is a form of embodied remembering, just as Casey [6] argues that "erotic body memory" can be seen as one form of embodied remembering. Nonetheless, we focus on the above forms as they most closely spoke to the experiences our participants described in the diary study.

In order to connect our results with the presented forms of embodied remembering, we will refer to the presented forms of embodied remembering by mentioning the category in bold for the remainder of the paper, for example: "Cycling is an example of embodied skills memory".

2.3 Technology to support embodied remembering

There have been an increasing number of efforts to create technologies to support remembering (for example, see [4, 7, 11, 19]). One example of such a technology is "Nostalgia" [34]. This system uses tangibles to prompt remembering among elderly people using video and music. Another example is "Slide2Remember" that changes digital photos in a wall- mounted picture frame to invite the user to reminisce: it provides music if the user would like an extra reminder of the experience, supporting autobiographical remembering [23]. There are several similar systems that use tangibles to support autobiographical remembering [4, 6, 10, 16, 22]. This hints to us that embodied interaction and remembering can go well together. However, for presenting the memory cues these prior works rely on other modalities, such as visual or auditory cues. What about technologies for memory support that incorporate bodily movement as a way for accessing memories?

There are not many systems that use bodily movement as a way to access memories. One example that does is "Momentum" [11]: it adds a specific movement to the moment a memory is captured - in this case, an accordion-like movement to operate a camera shutter. However, this movement is not intended to help the user to actually remember that moment at a later time, but rather to reflect on their bodily movements in the moment [11]. Another example of using movement for encoding memories is "NeverMind": the person can create a "memory palace" by using augmented reality glasses to place digital memory cues in their physical world [37]. The person can train their memory by walking through their "memory palace" [37]. Both examples use movement as a way to emphasise one aspect of the remembering process: "Momentum" [11] emphasises on the moment of encoding, while "NeverMind" [37] uses walking in the real world as part of the encoding and training of memory.

Other technologies utilise the development of embodied skills memory. One example is "TangibleRubik" [33]: a way of creating tangible passwords by rotating an object similar to a Rubik's cube. Study participants were able to recall passwords of 7 to 10 moves long after just a short period of use [33]. Another example is "NaviArm" [29], which uses robotic arms worn as a backpack to guide the movement of the person wearing it. Early results suggest that "NaviArm" supports learning sequential movement [29].

However, motor learning is only one form of embodied remembering, hence our understanding of how to design for embodied remembering is still incomplete.

In terms of design theory, we learned from Liu & Yang [27] principles for the design of interactions that support the use of motor memory – which is most closely related to embodied skills memory. However, their framework is specific to supporting embodied skill related to one technology (a Quick Launcher on a mobile phone), hence our understanding of how to design for embodied remembering, going beyond one particular form of embodied remembering and one particular technology, is still incomplete.

In summary, in this section we have presented what we learned from prior work. Our review has highlighted a gap in our understanding of how to design technology for embodied remembering. In order to begin filling this gap in knowledge, we start by answering our research question of how people use their bodies for remembering in everyday life in order to inform the design of future embodied remembering systems.

Figure 2: Examples of photo entries made by the participants. Left: the participant described storing her bike in a shed, which required a precisely executed sequence of movements. Right: the participant described making a cake and how she could feel the resistance of the batter through the whisks. The participant was an experienced baker and was able to use the sensed resistance to judge if the batter would lead to a good cake.

3 METHOD

We opted for a diary study using an online tool called Trello [43]. Diaries are often used in HCI since it allows participants to report their experiences and opinions instantly, in the participant's day-to-day environment, without the need to have the researcher present [14, 15, 40]. By using an online tool, we were able to capture data in varying forms of media (photos and text) [5].

3.1 Procedure

The diary keeping spanned three weeks. During this period, most of our participants experienced COVID-restrictions, such as lockdowns and work-from-home mandates. These restrictions are the reason we used an online tool (Trello [43]), which each participant used on their own device, e.g. a phone or tablet. To stay in touch with the participants we used emails and video calls. This approach allowed us to adhere to social distancing requirements, as approved by the ethics board of our institution.

There were three stages to the study: the first "preparation" stage aimed to prepare participants for the diary keeping (~30 minutes per participant), followed by the diary-keeping stage (three weeks, ~30 minutes a day) and, finally, the interview stage (~1 hour). We explain these next.

3.1.1 Preparation stage. The preparation stage consisted of a one-on-one 30-minute video call with each participant. This interview was used to sensitise the participant on the topic of embodied remembering, by providing an explanation of memory and embodied remembering, alongside a few examples, Next, the participant was given a walkthrough of the online diary template and how to use it. All participants opted to receive reminders during the diary study stage. We created 15-minute online calendar reminders that recurred twice every day for three weeks to remind the participant to fill out their diary, which were sent to the participant's email. Via this email the participants could add the reminders to their own digital calendars, allowing them to use their own preferred notifications settings.

3.1.2 Diary keeping stage. Diary keeping included the following steps: The participant was asked if they had an experience of using their body for remembering. If so, the participant was asked to create a copy of the empty diary card, one card for each experience. The participant then answered the questions on the copied diary card before indicating which parts of their body they used during that experience by drawing on the body template. The participants had the option to add photos of their described experiences (Figure 2). We estimate that the diary keeping took around 30 minutes a day. The participants could make use of 10-minute video call with the researchers every three days, during which they could ask questions, which were mostly about whether or not an example they experienced could be regarded as embodied remembering. In the discussions we encouraged participants to record all instances in which their body was involved in a remembering process. Additionally, we used these calls to ask the participants about their most recent diary entries. During these 10-minute calls the participants discussed which experiences were suitable for entry into the diary, which helped the participants in growing their understanding of embodied remembering.

3.1.3 Interview stage. After the diary study stage, each participant was invited for an interview via video call. During the interview, the participant was given the opportunity to elaborate on their diary entries. We used a semi-structured interview format [36], using a list of questions as our guide, for example: "When did you find such [referring to diary entry] bodily movement useful for remembering?" The interviews were video recorded and lasted for 46 minutes on average, with the shortest being 18 minutes and the longest 1 hour and 8 minutes.

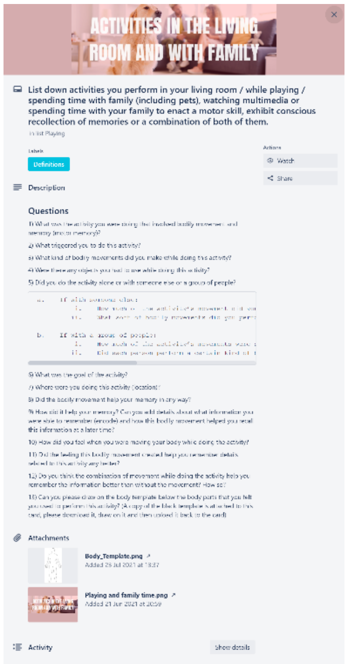

Figure 3: An example of the diary card when opened in the online diary template.

3.2 Diary design

Each Trello diary template consisted of: 1) an explanation of memory in general and embodied remembering specifically (including reference to the more colloquial term "motor memory") to help the participants decide which situations would be suitable to enter into the diary; 2) a list of examples of embodied remembering; 3) "diary cards" in the form of a Trello entry that the participants could use to fill out their diary entries (Figure 3). These diary cards were organised by activity or location to support the participants in thinking of possible instances that are linked to certain locations and the activities they performed there, such as activities in the living room or activities in the bathroom. Each diary card contained 13 questions and a body template (Figure 3), which shows the outline of a human body, aiming to prompt participants to think deeply about their remembering experiences and what role their body played in this (Figure 4). Examples of questions were: "Did the bodily movement help your memory in any way?"; and "Can you please draw on the body template below the body parts that you used to perform his activity?"

3.3 Participants

The study involved 12 participants from various locations, at various ages, and with various occupations (Table 1). The mean age was 35 years old, ranging from 22 to 62 years (SD=13,7 years). The participants were asked to self-describe their gender: six participants identified as female, five as male and one participant as non-binary/gender diverse. The participants were recruited through advertisement using a recruitment poster.

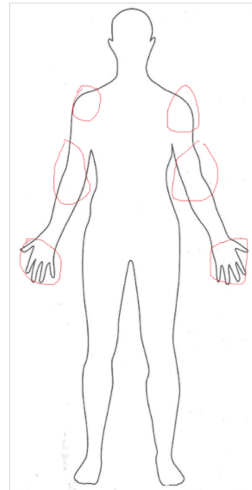

Figure 4: Example of a sketched-on body template. This template was an attachment to each diary card. The participant marked the arms as the body parts that helped with remembering.

3.4 Data sources and analysis

The used data sources are the diary cards and the transcripts from the interviews. The data from each diary was exported to a Word file and included the text entries, any photos the participants uploaded and their body templates. The audio was transcribed and then coders familiarised themselves with the transcripts before they commenced with the thematic analysis.

This source material was used for reflexive thematic analysis [6] and entered into NVivo [32]. Three coders performed individual coding on the data. The coders performed three rounds of coding in total, each taking a week to complete. After each round of coding, the coders compared their results, discussed any conflicts and merged their results into a single file, which was then used for another round of individual coding. After the final round of coding, the resulting files were merged. The coders then extracted overarching themes from the codes by entering all the codes into Miro (an online whiteboard app [48]), and grouping codes together. We describe the resulting themes next.

4 RESULTS

Overall, the analysis suggests that the study made the participants more aware and understanding of their embodied remembering experiences. The awareness mostly came from the reflections the participants had on their experiences while they recorded these in the diary.

The coding process resulted in 250 codes. The intercoder reliability was calculated using an unweighted Cohen's kappa [26], which resulted in a score of 0.85 across all codes, indicating the rigour of our research.

In the following sections we present our findings as embodied remembering experiences (ERXs). Each ERX describes a way in which embodied remembering was experienced by the participants. The ERXs are organised under four themes. The themes are: 1)

Table 1: Participant demographics.

Participant (pseudonym)	Gender	Age	Occupation	Location	COVID-19 restrictions
Amber	Female	62	Retired neuropsychologist	Australia	Lockdown [8]
Carlo	Male	29	PhD candidate	Brazil	No restrictions [31]
Daria	Female	31	Senior experience designer	Australia	Lockdown [8]
Eduard	Male	57	Roboticist	United Kingdom	No restrictions [42]
Falgu	Male	22	Student	India	Some public spaces closed, [44]
Ganavi	Female	55	Doctor	India	Some public spaces closed [44]
Heart	Female	25	Research assistant/programmer	Australia	Lockdown [8]
Isaac	Male	24	Research assistant	United States of America	Only local restrictions [47]
Johnathan	Male	26	PhD candidate	Australia	Lockdown [8]
Kamala	Female	30	PhD candidate	Austria	Some restrictions (e.g. mask wearing) [30]
Lien	Non-binary/ gender diverse	33	PhD candidate	Australia	Lockdown [8]
Reya	Female	26	Engineer	Colombia	Only local restrictions [21]

Remembering depends on the context (Section 4.1), 2) Practice makes better (Section 4.2), Turning knowledge from tacit to explicit (Section 4.3) and Movement serving as a memory aid (Section 4.4). One ERX can be related to more than one theme, but each ERX is only discussed in the theme it is most strongly related to (Figure 5).

4.1 Theme: Remembering depends on the context

The participants described how the context (the physical environment and the artefacts in it) helped them with embodied remembering. The impact of context on remembering is explained by Sutton & Williamson [41]: "Location, state, and nature of our bodies both at the time of the original experience and at the time of later retrieval drive what and how we remember". We saw this mentioned in the form of the influence of (the changes in) the environment, and the influence of artefacts.

The physical environment appeared to support the participant's embodied remembering in multiple ways. Firstly, the physical environment appeared to afford certain activities, such as a swimming pool that affords swimming (Reya), or a skating rink that affords hockey on skates (Carlo). Remembering previous experiences in that environment helps with executing embodied skills memory: it engages our spatial memory by remembering our plans and previous experiences in the space [39]. One example is Reya's response to rain, which changed the physical properties of the rugby field. Reya's memories of earlier rugby games in the rain helped her to effectively alter her bodily movements when the weather changed during the game. Finally, spatial memory is also used to move around efficiently in familiar environments [39]. According to the diary entries, this can, for example, take the form of knowing where furniture is.

However, we saw that relying on spatial memory can backfire. For example, Amber described her experience taking a different route than usual on her walk to a friend's house: *"Actually, the movements kind of confused my memory [...] we were approaching her house from an unusual direction and when we turned onto her street, I wasn't sure which direction to go because we had not approached from the usual way."* Amber's experience echoes Schusterman's [39] statement that change in the environment can make remembering more difficult.

Similarly, familiarity with an environment can easily be taken away when the environment is changed. For example, Falgu described: *"Having recently reorganised my room, I had to locate the bedside table in the dark by moving my hands around. However, I am now able to visualise exactly where the table is."* It took Falgu some time to become as familiar with his changed room as he was with the old setup.

Finally, the participants reported that in most cases of embodied remembering, an artefact was involved. The context in which the artefacts were being used appeared to support the participant in their activities, such as when Reya uses the baking utensils she has used, and how she has used these, to know at which step she is in a cake recipe. The use of artefacts for remembering is different from using artefacts as part of an embodied skill (Section 4.2): in the case of remembering, the person relies more on spatial memory and embodied autobiographical memory by asking themselves "have I performed this bodily movement yet?", than embodied skills memory, where one might ask "how did this bodily movement feel previously?"

The previous examples show successful instances in which the context influenced embodied remembering. However, the effect of context of embodied remembering becomes apparent when trying to apply embodied skills in a similar but slightly different context. This appears to result in a mismatch between spatial memory and the embodied skills that are called upon based on spatial memory (Section 4.3). Commonly occurring examples involved typing, where sometimes the keyboard was the culprit of the error, like

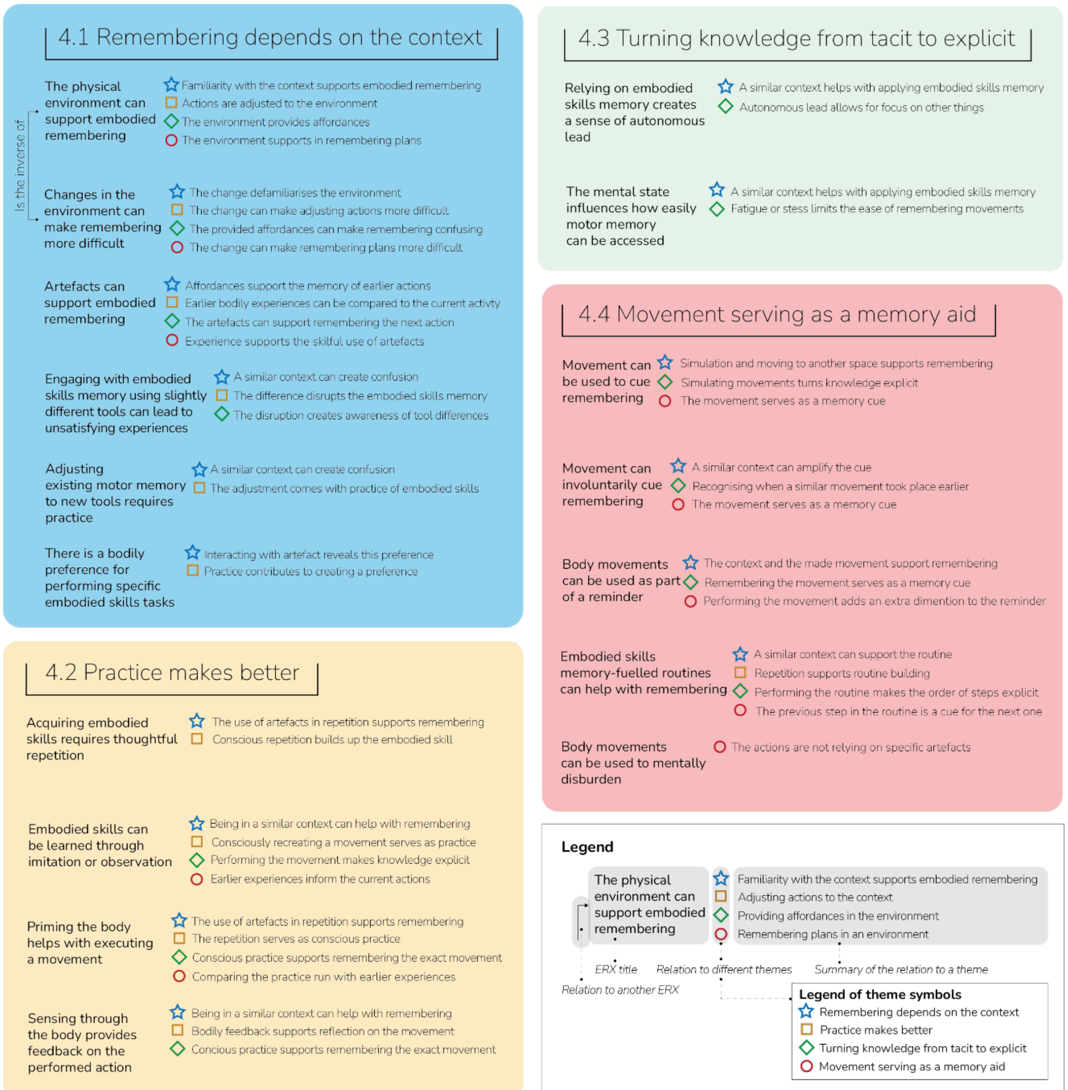

Figure 5: An overview of the themes with all embodied remembering experiences (ERXs) discussed under each theme. Each rectangle represents one theme and is marked with the corresponding subsection. Under each theme we placed all ERX that are most closely related to that theme. However, each ERX belongs to one or more themes, which we visualised by placing symbols after each ERX. Each symbol corresponds with a theme. For each related theme, a short relation description is provided.

Kamala's experience trying to type on an unfamiliar German keyboard. Luckily, the body can get used to the new context after a while, like how Kamala got used to a different braking system on her bicycle: *"Just this switch between using your hands to brake the back brake, put a brake on a bike versus just paddling in the opposite direction to brake was so tricky for me. It took me a lot of practice."* This adjustment is testimony to the flexibility of embodied skills memory: it can be adapted to different circumstances and needs [41].

With describing implicit body memory, we already described how the body is not without bias when engaging in embodied remembering. We can illustrate this bias with three instances in which hand preference was mentioned. Ganavi, for example, transferred her shopping bag to her left hand, to free up her right hand to open her door with. Ganavi described this action as "involuntary" and based on her experience of opening the door with her right hand. Similarly, participants reported being able to better perform embodied skills memory with the body part that is usually used in performing that skill. Amber illustrated this with her account of playing badminton with her non-dominant hand: *"Serving was impossible, you know, like you actually had to think about every movement, to get the shuttle across. So that made it quite obvious that I was terrible with one hand."* Though Amber had much practice in playing badminton with one hand, these skills were not transferrable to the other hand: the body part engaged most often in the activity had the most developed embodied skills memory related to it.

4.2 Theme: Practice makes better

Our second theme is "Practice makes better", encompasses acquiring embodied skills memory, to preparing the body to perform an embodied skill, and using bodily feedback to reflect on the performed bodily movement.

The participants reported several ways in which they acquired embodied skills memory. The first way involves thoughtful repetition. Reya described this as part of her learning process for a new CrossFit movement that involved raising a barbell over her head: *"So the way they teach us new movements is by phases. [...] So for example, you have to [start] from the stick, you have to put it over your head, right. So, they first tell you like, the first stage is just pulling into your chest. Second stage is just rotating your shoulders. And the third stage is like going down to the stick."* Reya explained how the movement is practised repeatedly and consciously, adding a layer of complexity once a sequence is mastered, quite in line with Fitts & Possner's model of skill acquisition [12]. Once embodied skills memory is acquired, there was a going back and forth between automatic and conscious bodily movement [12], for example in Amber's accounts of knitting. She started by describing how she knits when she is doing a well-known stitch for multiple rows: *"You don't have to be counting. [...] It becomes very, very automatic."* Then, she reflected on switching between conscious and automatic bodily movements: *"This line had a lot of different kinds of stitches. So, you had to pay attention to which stitch you were doing. You had to count how many there were."*

The second way of acquiring embodied skills memory was through observation and imitation, which both play a role in social implicit memory and embodied skills memory. For example, when Falgu tried to teach his friend the proper snooker stance: *"Even after I had taken that stance, I couldn't explain it as well. But I would be more like, "Just look at what I'm doing". And then trying to imitate that serve, just avoid explaining it, putting it into words and just ask them to follow it."* Falgu took on the role of a teacher (part of social implicit memory) and in this role he used his explicit knowledge of a movement to teach, thus relying on embodied skills memory.

Embodied autobiographical memory can be used to copy bodily movements that we remember other people performing. Isaac used his memory of watching the movements that his mother made while cooking to recreate her recipe. Though Isaac's mother was not there to give feedback, his past observations and imitating his mother's movements appeared to help Isaac with recreating the recipe [20, 41].

Practicing embodied skills memory can be done right before performing the skilled action. This 'priming of the body' is concerned with preparing the body for the execution of a bodily movement. As Heart described: *"I noticed that as I was painting, I often prepared my next paint/colour/water consistency, and with my brush, I would finally clean off a bit of paint on my palette with the same type of stroke strength/speed that I was planning to do on the canvas, as if to practise it."* Priming the body can be seen as calling embodied skills memory to action: priming supports planning out future movements by recreating the movement from the memory of earlier performances through simulating the bodily movement before executing it [20, 41].

According to the participant's reports, it appeared that the built-up embodied skills memory can be used to reflect on the bodily movement by comparing their body sensations to earlier instances of performing the same movement. One example of this is Carlo practising skating: *"Whenever I felt like I was losing balance while skating backwards, I'd feel like I was about to fall on my knees. That made me notice I was standing up too straight, so I remembered that I should bend my knees way more."* Carlo's example demonstrates how he used sensing through the body as a form of feedback on his performed action, and adjusted accordingly.

Artefacts were used as part of proprioceptive feedback, for example when Reya was baking: *"[I would] whisk the texture and how it feels when I was making this [whisking] movement when I was mixing with the rest of the ingredients. So, if it has a specific texture that I knew was a good texture."* This example illustrated the way in which the tool became part of the embodied memory: the tool expanded the body schema and thus became part of the experience of the world [24]. The created memories therefore include what was experienced through that tool. Apart from supporting embodied skills memory, artefacts can be used to support spatial memory [20], which Isaac described in his account of looking for a suitable pot for his plant at a plant nursery by holding his hands in the air to simulate holding a plant he has at home.

Finally, proprioception was used to become more aware of one's own movements, which was then used to explain that movement to someone else. For example, when Carlo taught his friend how to cycle: *"I would tell them to do something, they would try it, and then they maybe couldn't do it. So, I tried to do it myself. And then try to really pay attention to what sort of movements I was doing, like, what did I do to try to balance myself? And then, after analysing that, coming back to them and saying, 'Oh, I think what you need to do is like, put your weight to this side'."* This example suggested that in order to teach someone the movements to an embodied skill, the teacher benefits from having explicit knowledge of their own embodied skills memory. Obtaining this explicit knowledge requires effort: as Dourish [10] explained, we often tacitly know what to do, but we have a difficult time actually articulating what we are doing. Conscious movement, however, can support the recall of movements [41].

4.3 Theme: Turning knowledge from tacit to explicit

This theme highlights embodied practices that turned what participants experienced through their bodies into explicit expressions of those experiences. This experience is based on relying on embodied skills in the form of what we call autonomous lead, and factors that impact the ability to rely on these skills.

Autonomous lead can be described as relying on the automation that is part of embodied skills. This is reflected in Reya's account of swimming: *"I swam using freestyle, and there's some points of the technique in which I focus, for instance, the kicking. I consider that most of the time I breathe automatically because it is a movement that I have very coordinated."* Reya's example shows how this autonomous lead is related to acquiring embodied skills (Section 4.1):

the automation leaves room to further practise certain aspects of the movement sequence.

This autonomous lead can also be used to access tacit memories. Multiple participants reported using their typing skills to come up with what to write, but used different strategies: Lien would type and delete words repeatedly, Jonathan would just start typing random words, and Amber described it as *"letting [her] fingers decide what to type"*. In each example the participants had an implicit idea of what to type, but it took letting the body take the lead to actually put it into words. This use of automation appears more linked to spatial memory, in the sense that we use our body to engage with an artefact in order to remember our plans [39].

However, it appears that the ease of accessing embodied skills memory depended on the mental state of the participant: fatigue and stress were two factors that had an influence. Reya explained how stress made it more difficult to remember properly: *"When I'm excited, I have more focus on my play role and can remember the actions that I should perform in order to defend or attack better. When I feel pressure, it is hard to remember the key factors of the movement to perform it consciously."* In this case, Reya did not have the capacity to focus on certain aspects of her embodied skills memory due to the pressure she experienced.

4.4 Theme: Movement serving as a memory aid

Movement serving as a memory aid aims to use the body to support the memory outside of motor memory. We encountered four ways in which this was achieved: using bodily movements to cue memories, movement as a reminder, relying on embodied skills routines and body mental disburdening.

The participants reported different ways in which moving the body helped with cueing memories: simulation and moving in an environment. To illustrate the first, we use Jonathan's description of using his body to mimic eating a burger to remember which ingredients he had to get for dinner while being in the supermarket: *"It triggered mental imagery of eating a burger. Then I could see the burger and all its ingredients layered out in my mind like it was a [TV] commercial where all the ingredients of the burger get stacked on each other in slow motion."* In this case, the simulation of the movement supported the formation of the mental image, which in turn helped with remembering – a list of groceries, in this case. Moving in the environment, on the other hand, was used to overcome the "doorway effect", which describes the experience of forgetting what you intended to do after passing a doorway [36]. Moving back to the original environment speaks to spatial memory [39].

Jonathan's example suggests that embodied autobiographical memory can be activated intentionally, by, for example, simulating movements [20, 28, 41]. However, movements can also involuntarily cue memories simply because of the similarities between the cue and the movement that is part of the memory [41], like Daria's experience: *"Jumping up on the [kitchen] bench didn't specifically remind me of anything specific to cooking, but it reminded me of a dream I had a few nights ago where I was at my old family house and my brother told me that in this house we always sit on the kitchen benches."* Daria reported that she was *"taken aback"* by this memory, as she did not expect it.

Apart from using the body to cue a memory, the body can also be used to set reminders [41]. We can illustrate this with Daria's experience: she was lying in bed and realised she needed a reminder to get chicken out of the freezer for the next day. Her solution was to throw her slipper towards the bedroom door as a reminder. Daria: *"In the morning I hoped to see the slipper and remember the chicken but when I woke up I actually remembered the action of throwing the slipper and remembered the chicken."* In other words, it was the memory of the physical bodily movement that appeared to help Daria to remember her plan.

In everyday life we often repeat the same movements in the same sequence. These routines are part of our embodied skills memory and are built up of "habitual movements": movements that we can perform without much conscious effort [6, 27, 32, 41]. For example, Amber described a morning exercise routine in which she performs lunges from her bedroom to her bathroom, where she keeps her medication: *"I always use this as a cue to get a glass of water and take a tablet at this point in my exercise routine."* She elaborates: *"I am more likely to forget to take the tablet on days I'm not doing the morning exercises."* Not performing a routine can break down other parts of the routine.

Finally, the participants reported that they used their bodies as a memory aid by using it to limit their mental load. This form of embodied autobiographical remembering [18, 28] was expressed in the participants' accounts in two strategies. Firstly, gaze aversion, which involves moving the head looking slightly up and to the side as a way to limit visual stimuli [1, 38], was reported by Jonathan, Heart and Daria. The second strategy was fidgeting [22]. Participants had their own ways of fidgeting: Daria liked to tilt and drop a trackpad, Lien preferred pen twirling while thinking about what to write and Isaac noticed he liked to gently pull his fingers.

5 THE EMBODIED REMEMBERING EXPERIENCE (ERX) FRAMEWORK

In the previous section we discussed all the different embodied remembering experiences (ERXs) that our participants reported. To support future design efforts for technology that supports embodied remembering, we placed all ERXs into two dimensions (Figure 6). These two dimensions characterise each ERX: "skilled versus unskilled bodily movement" on the X-axis, and "conscious versus subconscious bodily movement" on the Y-axis.

We use these axes to place the four themes, which cluster the ERX: "Remembering depends on the context" encompasses all ERXs within the dotted line, "Practice makes better" is represented by the yellow shape, "Turning knowledge from tacit to explicit" with a green oval, and "Movement serving as a memory aid" is the red shape.

The X-axis was chosen because different ERXs involved different levels of skill. Skilled bodily movements rely on embodied skills memory, which is built up over time [10, 32, 39], as we saw in Reya's conscious repetition to learn a new CrossFit move, Carlo's ice skating, and Amber's knitting. Unskilled bodily movements, on the other hand, do not require the same training as embodied skills [6, 32]. Examples of unskilled bodily movements are gaze aversion and fidgeting (Section 4.4).

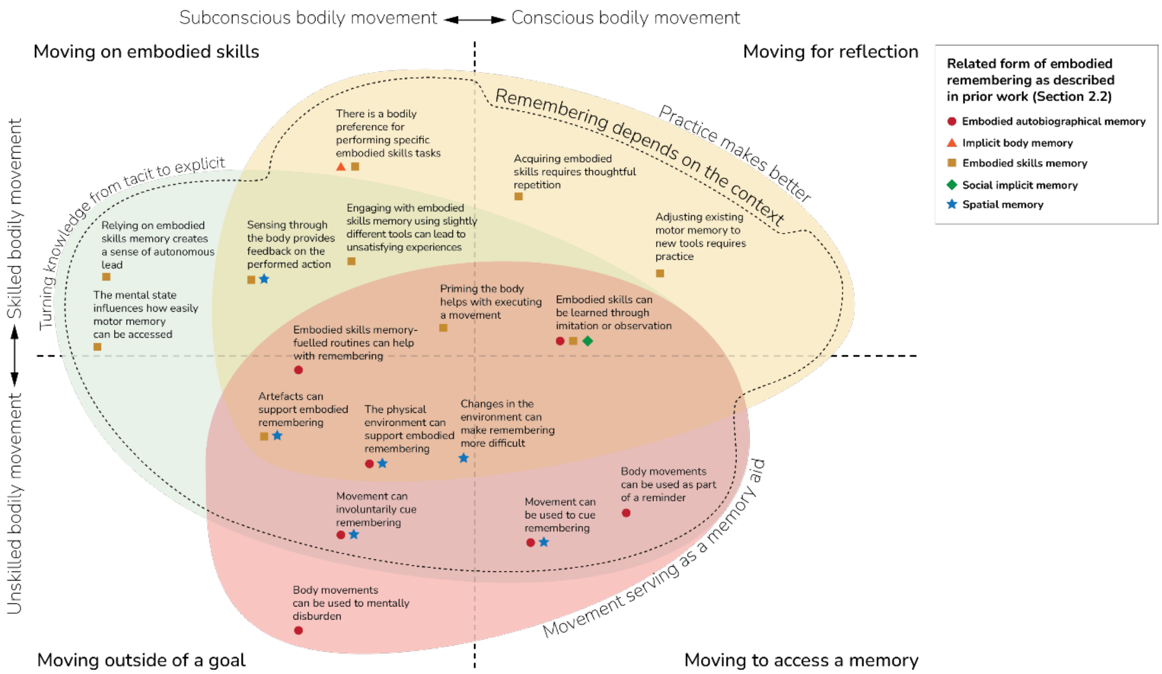

Figure 6: The Embodied Remembering Experience (ERX) framework.

The dimension on the Y-axis, "conscious vs subconscious bodily movement", was chosen because the participants reported explicitly performing certain actions subconsciously (like Ganavi switching her shopping to her other hand, Section 4.1), and other actions with much conscious attention (like when Carlo taught his friend to ride a bicycle, Section 4.2). Conscious bodily movement requires constant attention, e.g., Heart priming her brush stroke (Section 4.2). Subconscious bodily movement is performed without much attention [8, 23, 29], like fidgeting (Section 4.4).

The placement of each ERX on the two axes is related to the level of conscious attention and level of skill involved in the performed movements. This placement reveals that "Practice makes better" relies more on skilled movement, while "Movement serving as a memory aid" makes use of more unskilled movements. "Turning knowledge from tacit to explicit" was characterised by relying more on subconscious bodily movement than the other themes.

The two dimensions created four quadrants, each representing a category of movement based on the intention behind that movement and which are defined by the level of skill and conscious attention related to that particular category of movements. We formulated the descriptions of these quadrants based on the ERX that are placed in each quadrant. These quadrants will help us categorise different strategies to support design for embodied remembering. The four categories are:

- **Moving on embodied skills:** This category involves skilled and subconscious bodily movement. The intention is to be able to move skilfully without conscious effort in order to pay attention to other things, like Reya being able to focus on her breathing technique while swimming (Section 4.3).
- **Moving for reflection:** This category involves bodily movements that are skilled and conscious. The intention behind these movements is to reflect on the movement and the associated body sensations in order to remember, such as Heart practising her brush strokes before painting on the canvas (Section 4.1), or using a different keyboard than usual (Section 4.1).
- **Moving outside of a goal:** This category involves unskilled and subconscious bodily movement. These are bodily movements that are not part of the goal, but are in support of it, like fidgeting for stress relief (Section 4.4), or that create an outcome outside of the goal, such as a movement unintentionally cueing a memory (Section 4.4).
- **Moving to access a memory:** This category involves unskilled and conscious bodily movement. The person's intention with such movements is to remember something specific. These include movements to cue remembering (Section 4.4), using the body as part of a reminder (Section 4.4) or relying on body routines to remember something (Section 4.4): there is a goal to these movements, but no skill is required.

The presented framework is not exhaustive: it only covers some but not all forms of embodied remembering, and there are likely more ERXs to uncover with future work. Nonetheless, the ERX framework offers us a starting point for describing design strategies for the development of technology for embodied remembering.

6 STRATEGIES FOR THE DESIGN OF TECHNOLOGIES FOR EMBODIED REMEMBERING

We now use the categories of movement for remembering, as per the quadrants of Figure 6, to identify strategies for the design of technologies for embodied remembering (Figure 7). We identified eight design strategies for embodied remembering. Each strategy is placed in relation to the ERXs that are most likely to benefit from the application of that strategy. Four of these strategies sit neatly in each of the quadrants. However, we also identified three that could support skilled bodily movement but should provide support for both conscious and subconscious movement, while our strategy "augmenting the environment" sits in the middle as it is independent of skilled and conscious movement, speaking to our (almost) "all encompassing" context theme (which we explain later). We discuss each strategy in relation to the four categories:

- **Moving on embodied skills:** Technology could support moving on embodied skills through the following strategies: 'creating representations of the movement', 'create and refer to recordings of personal movements', and 'providing clues for the next step in an embodied skills routine'. 'Creating representations of movement' might take the form sketched representations of choreographed movements [8], or, for a high-tech solution, a vibromotor suit like EmbodiSuit [4]. To specifically support 'providing clues for the next step in an embodied skills routine', the technology could support applying an existing embodied skill onto another context, such as nudging fingers towards the correct keys when using hotkeys with new software.
- **Moving for reflection:** Technology could support moving for reflection through the following strategies: 'providing tools for imitation', 'creating and referring to old recordings of their own bodily movements', and 'providing clues for the next step in an embodied skill routine'. These strategies promote conscious repetition of bodily movements and the development of skilful bodily movements, both of which are needed for embodied skills memory. With a teacher present, the technology can 'provide tools for imitation', for example through an exoskeleton or electro-musculography (EMG) system that records the teacher's movements. Then, the student would experience these recordings, similar to NaviArm [29] or Wearable Choreographer [2] that use indicators placed on joints that light up or vibrate when the student is in the correct position. When a student is practicing by themselves, they can 'create and refer to old recordings of their own bodily movements', for example with clay: a hand that is holding clay is positioned so it represents the desired skilled movement. After the clay has dried, it has a tangible recording of that hand position. Alternatively, the student could use a technology that gives 'clues about the next step in an embodied skill routine', such as an AI mirror that shows the next step in a choreography as soon as the person stops moving [46].
- **Moving to access a memory:** Technology could support moving to access a memory through the following strategies: 'supporting the encoding of memories' and 'augmenting existing remembering'. These strategies aim to support mainly embodied autobiographical memory by promoting conscious yet unskilled bodily movements, such as simulations. The 'supporting the encoding of memories' strategy aims to add the modality of movement to a memory, thus making it possibly easier to remember. Such technology could involve encoding challenge cards in a mobile phone app: each card describes a movement. The person uses the described movement in a situation that they need to remember. For example, to not forget they locked the front door, the app (based on location-data) suggests performing the movement, e.g., a pirouette, right after they locked the door. The unusual movement might help the person in a similar way that Daria used the bodily movement of throwing a slipper to remember to take something out of the freezer (Section 4.4). An example of 'augmenting existing remembering' is nudging a person to walk to a previous location to overcome the 'doorway effect', for example by means of AR glasses providing directions, as inspired by Lakehal et al. [25].
- **Moving outside of a goal:** Technology could support moving outside o' a goal through the following strategies: 'promoting existing embodied remembering strategies' and 'augmenting existing embodied remembering strategies'. Through these strategies the user could be supported in utilising existing ERXs that require no skilled movements and little conscious attention. In terms of 'promoting existing embodied remembering strategies', designers could create a fidget item that asks for attention, similar to Wobble [45] , but with the aim of cognitive offloading. When the person prefers gesturing as a memory aid, EMS could be used to, for example, activate a tapping finger. Augmenting technologies could provide new cues for engaging in embodied remembering, for example a technology that promotes looking away (Section 4.4) by offering a projection of lush greenery to avert one's gaze to.

A strategy that could be used across all four quadrants is 'augmenting the environment'. However, the application of this strategy differs with each quadrant. For example, to support moving for reflection, we can augment the environment to have virtual memory cues (e.g. NeverMind [34]). To support moving to access a memory, the augmentation can involve shutting out sound or sight to lower the cognitive load. When moving outside of a goal, this augmentation could involve playing white noise whenever a person starts to fidget in order to support mental disburdening. And when a person is moving on embodied skills, similarities between the current environment and the environment in which an embodied skill is commonly used can be emphasised to make accessing that embodied skill easier, for example by using a projector that highlights these similarities.

7 DISCUSSION

In the previous sections we presented the ERX framework (Figure 6) and design strategies for embodied remembering. In this section,

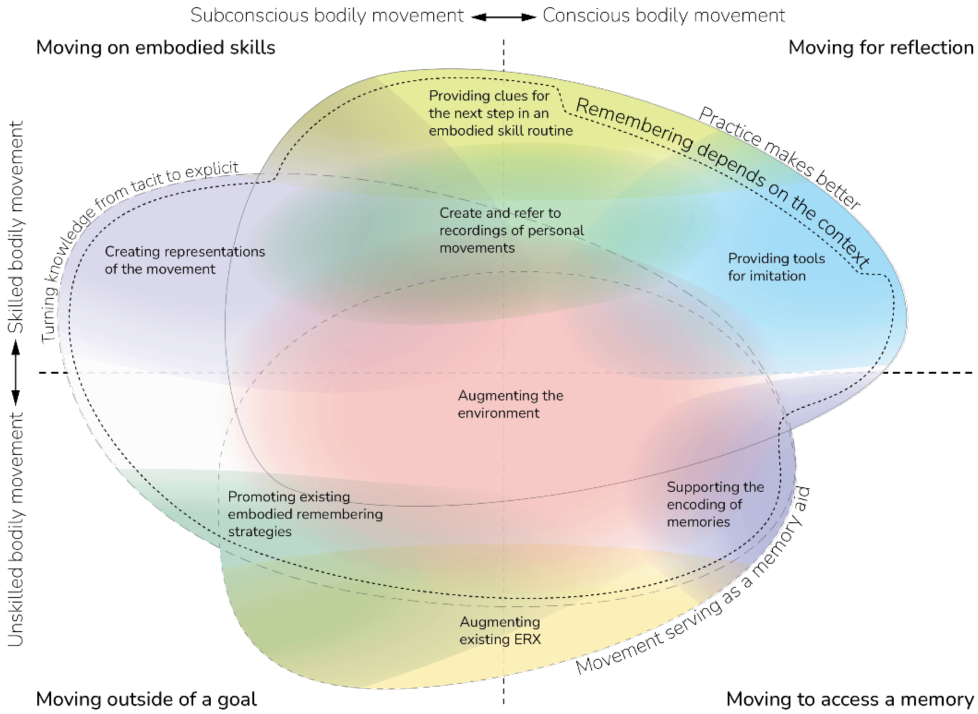

Figure 7: The design strategies for embodied remembering.

we will first discuss our results and framework in relation to related work. We follow with a discussion of the implications of the technologies developed using the proposed design strategies.

7.1 Discussing our results in relation to related work

In contrast to many memory-related findings based phenomenological practice (which mostly relies on observations), our findings are based on the first-hand accounts of the people experiencing embodied remembering. Our participants' ERXs speak to various forms of embodied remembering previously suggested in prior work (Section 2.1) [6, 18, 20, 27, 32, 39, 41]. Hence, our results empirically confirm prior work and brings it to the field of HCI. Interestingly, several ERXs speak to multiple forms of embodied remembering as described in prior work. For example, "Movement can be used to cue remembering" (Section 4.4) speaks to embodied autobiographical remembering by simulating a movement [18, 25, 39], such as Jonathan's simulation of eating a burger (Section 4.4), but it also speaks to spatial memory by walking back to the location where a plan originated (Section 4.4) [39]. This confirms prior theory that forms of embodied remembering are not strictly ordered, but flow over into each other [41].

Additionally, we see that some forms of embodied remembering are more represented in certain themes. Embodied skills memory, for example, is represented in most ERX that are part of the theme "Practice makes better", because this theme focuses on the acquisition, use and analysis of these embodied skills. At the same time, embodied autobiographical remembering [41] is only linked to ERX that are part of the theme 'Movement serving as a memory aid', since the ERX in this theme were the ones most commonly used to support embodied autobiographical remembering (Section 4.4). Spatial memory [39] was mostly linked to ERXs where the environmental context played an important role, such as the ERX 'Movement can be used to cue remembering'. In these ERX, the environment either provided additional cues to the embodied cues, or the environment was linked to built-up embodied skills memory [39] (like Falgu getting used to his new room setup, Section 4.1, or the example of stubbing one's toe after moving a table, Section 2.2 [39]).

Our work expands on the existing understanding of embodied remembering through the created ERX framework. This framework describes the different ERX in terms of the conscious effort and skill that is behind the involved movement. In Figure 6 we see that different forms of embodied remembering can rely on different levels of conscious effort and skill. For example, embodied skills memory can rely on conscious movement (such as Reya practising a new CrossFit move, Section 4.2, similar to Fitts & Possner's model of skill acquisition [12]), or subconscious movement (Reya relying her trained breathing while swimming, Section 4.3, or being able to focus on traffic while cycling [41]). In the mentioned cases the involved movement supported remembering, but relied on a different amount of conscious effort.

By organising the ERX on the two axes, we see how different ERX can support different intentions behind embodied remembering, which is reflected in the four categories. Through mapping the ERX to these categories, we were able to formulate strategies for enhancing an ERX in order to support that intention.

7.2 Implications of technologies based on the proposed design strategies

The participants' accounts show that embodied remembering is not without flaws. They reported that embodied skills memory can break down due to changes in the environment (Section 4.1, related to spatial memory [39]), or when applied in a context that appears similar, but is not (Section 4.1). Access to embodied skills memory appears to change based on the person's stress or fatigue (Section 4.3). Additionally, embodied skills memory requires conscious, repetitive practice in order to become "automatic" (Section 4.3). And finally, remembering can be involuntary (Section 4.4). Technologies that support embodied remembering can be of support in each of these cases. The ways in which these technologies can support embodied remembering was shown in Figure 7.

The speculated technologies in Section 6 speak to the incorporation of movement as an interaction modality. Using the definition of embodied remembering from Section 2.2, we use our entire body to remember [20, 28, 41]. This embodiment encompasses all senses, including proprioception [10], implicating that the modalities that can be used in technologies for embodied remembering can extend beyond vision and sound, to incorporating movement (as evidenced in Section 2.3, [9, 11, 23, 34, 37, 45]). However, the few examples in Section 2.3 show that movement is rarely addressed in technologies that support remembering. Movement can add to the multimodality of technologies that support remembering. Memories are a composite of multiple sensory experiences [41], thus offering an additional modality can offer an extra cue that supports in remembering. Our proposed design strategies can support designers and HCI researchers in addressing embodiment in general, and movement specifically, in their technological endeavours to support remembering.

8 LIMITATIONS AND FUTURE WORK

We believe that our research revealed interesting insights thanks to, among others, the differences between individual participants and the richness of their responses. This shows itself in having 9.5 hours of interviews and 170,174 words in the thematic analysis. However, there is the opportunity to capture additional data using other tools, such as asking participants to wear cameras (as suggested previously [36]), expanding the duration of the study, for example to a year, and seeking more variety in backgrounds. Quantitative methods could further supplement the data, for example by performing motion capture.

Although our work does not confirm other forms of remembering (e.g. traumatic or erotic body memory, see Section 2.2, [6, 39]), we do not reject these although our study did not lead to any such entries in the diaries. This could be attributed to the explanation and examples that we provided to participants, as well as the participants being possibly hesitant to record certain experiences, such as traumatic or sexual experiences. We did not aim to record these experiences, since our study was designed to record everyday embodied remembering experiences that participants were willing to share.

Secondly, COVID-19 restrictions influenced the diary entries. As Jonathan noted, the study coupled with the restrictions revealed the "repetitive nature of our daily lives": the same activities recurred almost daily and the participants were reluctant to fully fill out duplicate diary entries or used other solutions like commenting "+2" to indicate duplicates. It is to be expected that research performed without these restrictions could capture a larger variety of activities in more diverse contexts.

The study was cognitively demanding: several participants noted that the time needed to answer questions (approximately 30 minutes per day) was quite difficult to find during the entirety of the three weeks. Additionally, multiple participants noted that the template structure was useful, though it had its limitations. Some participants had experience with the online platform, but several had not. The latter group found using the templates a bit more difficult, especially when sketching on the body template. Several participants suggested offering multiple modalities: voice recordings, more emphasis on photography and offering more space to freely write about their experiences. Offering such modalities along with tools that require less time per day might lower the experienced cognitive load.

9 CONCLUSION

In this paper, we aimed to create an initial understanding of how people use bodily movements for everyday remembering in order to support the design of technology for embodied remembering. By means of a thematic analysis of the data from a three-week-long diary study with twelve participants, we uncovered a multitude of embodied remembering experiences (ERXs), leading to the ERX framework. We used the framework to suggest a set of strategies that could help design future embodied remembering technologies, which will in turn hopefully benefit people looking to improve their remembering.

ACKNOWLEDGMENTS

We would like to thank all of our participants for their time and effort. We also thank the Australian Research Council for funding our research.

REFERENCES

[1] Dekel Abeles and Shlomit Yuval-Greenberg. 2017. Just look away: Gaze aversions as an overt attentional disengagement mechanism. Cognition 168: 99–109. https://doi.org/10.1016/j.cognition.2017.06.021
[2] Catarina Allen d'Ávila Silveira, Ozgun Kilic Afsar, and Sarah Fdili Alaoui. 2022. Wearable Choreographer: Designing Soft-Robotics for Dance Practice. In Designing Interactive Systems Conference (DIS '22), 1581–1596. https://doi.org/10.1145/3532106.3533499
[3] Alan Baddeley. 2013. 1 What is Memory? In Essentials of Human Memory (Classic Edition). Taylor & Francis Group, London, UNITED KINGDOM, 1–18. Retrieved from http://ebookcentral.proquest.com/lib/monash/detail.action?docID$=$1331855. https://doi.org/10.4324/9780203587027
[4] Mendel Broekhuijsen, Elise van den Hoven, and Panos Markopoulos. 2017. Design Directions for Media-Supported Collocated Remembering Practices. In Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction (TEI '17), 21–30. https://doi.org/10.1145/3024969.3024996
[5] Scott Carter and Jennifer Mankoff. 2005. When participants do the capturing: the role of media in diary studies. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '05). Association for Computing Machinery, New York, NY, USA, 899–908. https://doi.org/10.1145/1054972.1055098
[6] Edward S. Casey. 1985. Habitual Body and Memory in Merleau-Ponty. In Phenomenology and the Human Sciences, J. N. Mohanty (ed.). Springer Netherlands, Dordrecht, 39–57. https://doi.org/10.1007/978-94-009-5081-8_4
[7] Ashley Colley, Juho Rantakari, and Jonna Häkkilä. 2014. Augmenting the Home to Remember: Initial User Perceptions. In Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing: Adjunct Publication (UbiComp '14 Adjunct), 1369–1372. https://doi.org/10.1145/2638728.2641717

[8] Department of Education, Skills and Employment. 2021. ECEC COVID-19 timeline. Department of Education. Retrieved September 15, 2022 from https://www.education.gov.au/covid-19/resources/ecec-covid19-timeline
[9] Jelle van Dijk. 2018. Designing for Embodied Being-in-the-World: A Critical Analysis of the Concept of Embodiment in the Design of Hybrids. Multimodal Technologies and Interaction 2, 1: 7. https://doi.org/10.3390/mti2010007
[10] Paul Dourish. 2001. "Being-in-the-World": Embodied Interaction. In Where the Action is: The Foundations of Embodied Interaction. MIT Press, Cambridge, MA, USA, 99–126.
[11] Dirk van Erve, Gerrit-Willem Vos, Elise van den Hoven, and David Frohlich. 2011. Cueing the Past: Designing Embodied Interaction for Everyday Remembering. In Procedings of the Second Conference on Creativity and Innovation in Design (DESIRE '11), 335–345. https://doi.org/10.1145/2079216.2079264
[12] P.M. Fitts and M.I. Posner. 1967. Human performance. Brooks/Cole, Oxford, England.
[13] Eberhard Graether and Florian Mueller. 2012. Joggobot: a flying robot as jogging companion. In CHI '12 Extended Abstracts on Human Factors in Computing Systems, 1063–1066. https://doi.org/10.1145/2212776.2212386
[14] Eiji Hayashi and Jason Hong. 2011. A diary study of password usage in daily life. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11), 2627–2630. https://doi.org/10.1145/1978942.1979326
[15] Serena Hillman, Tad Stach, Jason Procyk, and Veronica Zammitto. 2016. Diary Methods in AAA Games User Research. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, 1879–1885. https://doi.org/10.1145/2851581.2892316
[16] Kristina Hook. 2018. Designing with the Body: Somaesthetic Interaction Design. MIT Press Academic, Cambridge, Massachusetts.
[17] Kasper Hornbaek, David Kirsh, Joseph A. Paradiso, and Jürgen Steimle. 2018. On-Body Interaction: Embodied Cognition Meets Sensor/Actuator Engineering to Design New Interfaces (Dagstuhl Seminar 18212). Dagstuhl Reports 8, 5: 80–101. https://doi.org/10.4230/DagRep.8.5.80
[18] Elise van den Hoven and Ali Mazalek. 2011. Grasping gestures: Gesturing with physical artifacts. Artificial Intelligence for Engineering Design, Analysis and Manufacturing 25, 3: 255–271. https://doi.org/10.1017/S0890060411000072
[19] Elise van den Hoven, Corina Sas, and Steve Whittaker. 2012. Introduction to this Special Issue on Designing for Personal Memories: Past, Present, and Future. Human–Computer Interaction 27, 1–2: 1–12. https://doi.org/10.1080/07370024.2012.673451
[20] Francesco Ianì. 2019. Embodied memories: Reviewing the role of the body in memory processes. Psychonomic Bulletin & Review 26, 6: 1747–1766. https://doi.org/10.3758/s13423-019-01674-x
[21] Infobae. 2022. Estos son los criterios y condiciones para la reactivación económica en Colombia, según la resolución 777 de MinSalud. infobae. Retrieved September 15, 2022 from https://www.infobae.com/america/colombia/2021/06/03/estos-son-los-criterios-y-condiciones-para-la-reactivacion-economica-en-colombia-segun-la-resolucion-777-de-minsalud/
[22] Michael Karlesky and Katherine Isbister. 2014. Designing for the Physical Margins of Digital Workspaces: Fidget Widgets in Support of Productivity and Creativity. In Proceedings of the 8th International Conference on Tangible, Embedded and Embodied Interaction (TEI '14), 13–20. https://doi.org/10.1145/2540930.2540978
[23] Subin Kim, Sangsu Jang, Jin-young Moon, Minjoo Han, and Young-Woo Park. 2022. Slide2Remember: An Interactive Wall Frame Enriching Reminiscence Experiences by Providing Re-Encounters of Taken Photos and Heard Music in a Similar Period. In Designing Interactive Systems Conference (DIS '22), 288–300. https://doi.org/10.1145/3532106.3533456
[24] David Kirsh. 2013. Embodied Cognition and the Magical Future of Interaction Design. ACM Trans. Comput.-Hum. Interact. 20, 1. https://doi.org/10.1145/2442106.2442109
[25] Aymen Lakehal, Sophie Lepreux, Christos Efstratiou, Christophe Kolski, and Pavlos Nicolaou. 2020. Investigating Smartphones and AR Glasses for Pedestrian Navigation and their Effects in Spatial Knowledge Acquisition. In 22nd International Conference on Human-Computer Interaction with Mobile Devices and Services, 1–7. https://doi.org/10.1145/3406324.3410722
[26] J. Richard Landis and Gary G. Koch. 1977. The Measurement of Observer Agreement for Categorical Data. Biometrics 33, 1: 159–174. https://doi.org/10.2307/2529310
[27] Miao Liu and Xingchun Yang. 2020. On the Role of "Muscle Memory" in Interaction Design. In Advances in Industrial Design (Advances in Intelligent Systems and Computing), 634–640. https://doi.org/10.1007/978-3-030-51194-4_83
[28] Christopher R. Madan and Anthony Singhal. 2012. Using actions to enhance memory: effects of enactment, gestures, and exercise on human memory. Frontiers in Psychology 0. https://doi.org/10.3389/fpsyg.2012.00507
[29] Azumi Maekawa, Shota Takahashi, MHD Yamen Saraiji, Sohei Wakisaka, Hiroyasu Iwata, and Masahiko Inami. 2019. Naviarm: Augmenting the Learning of Motor Skills using a Backpack-type Robotic Arm System. In Proceedings of the 10th Augmented Human International Conference 2019, 1–8. https://doi.org/10.1145/3311823.3311849
[30] Markus Pollak, Nikolaus Kowarz, and Julia Partheymüller. 2021. Blog 135 (EN) - Chronology of the Corona Crisis in Austria - Part 6: A. Retrieved September 15, 2022 from https://viecer.univie.ac.at/en/projects-and-cooperations/austrian-corona-panel-project/corona-blog/corona-blog-beitraege/blog135-en/
[31] Martha Viotti Beck, Gabriela Mestre, and Marisa Wanzeller. 2021. Brazil Lifts Covid Restrictions as Cases, Deaths Finally Ease - Bloomberg. Bloomberg. Retrieved September 15, 2022 from https://www.bloomberg.com/news/articles/2021-08-03/brazil-lifts-covid-restrictions-as-cases-deaths-finally-ease
[32] Maurice Merleau-Ponty. 1962. Phenomenology of Perception. Routledge & Kegan Pau.
[33] Martez Mott, Thomas Donahue, G. Michael Poor, and Laura Leventhal. 2012. Leveraging motor learning for a tangible password system. In CHI '12 Extended Abstracts on Human Factors in Computing Systems, 2597–2602. https://doi.org/10.1145/2212776.2223842
[34] Magnus Nilsson, Sara Johansson, and Maria Håkansson. 2003. Nostalgia: an evocative tangible interface for elderly users. In CHI '03 Extended Abstracts on Human Factors in Computing Systems (CHI EA '03). Association for Computing Machinery, New York, NY, USA, 964–965. https://doi.org/10.1145/765891.766096
[35] Isabel Pedersen, Suneel Jethani, Andrew Iliadis, Deborah Lupton, Kevin Warwick, Katina Michael, M. G. Michael, Christine Perakslis, Roba Abbas, and Gary Genosko. 2020. Embodied Computing: Wearables, Implantables, Embeddables, Ingestibles. MIT Press, Cambridge, UNITED STATES. Retrieved from http://ebookcentral.proquest.com/lib/monash/detail.action?docID$=$6246542. https://doi.org/10.7551/mitpress/11564.001.0001
[36] Gabriel A. Radvansky, Sabine A. Krawietz, and Andrea K. Tamplin. 2011. Walking through Doorways Causes Forgetting: Further Explorations. Quarterly Journal of Experimental Psychology 64, 8: 1632–1645. https://doi.org/10.1080/17470218.2011.571267
[37] Oscar Rosello, Marc Exposito, and Pattie Maes. 2016. NeverMind: Using Augmented Reality for Memorization. In Adjunct Proceedings of the 29th Annual ACM Symposium on User Interface Software and Technology (UIST '16 Adjunct), 215–216. https://doi.org/10.1145/2984751.2984776
[38] Anaïs Servais, Noémie Préa, Hurter Christophe, and Emmanuel Barbeau. 2022. Why and When Do You Look Away When Trying to Remember? Gaze Aversion as a Marker of the Attentional Switch to the Internal World. PsyArXiv. https://doi.org/10.31234/osf.io/3tybc
[39] Richard Shusterman (ed.). 2012. Muscle Memory and the Somaesthetic Pathologies of Everyday Life. In Thinking through the Body: Essays in Somaesthetics. Cambridge University Press, Cambridge, 91–111. https://doi.org/10.1017/CBO9781139094030.007
[40] Anjeli Singh and Sareeka Malhotra. 2013. A Researcher's Guide to Running Diary Studies. In Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction (APCHI '13), 296–300. https://doi.org/10.1145/2525194.2525261
[41] John Sutton and Kellie Williamson. 2014. Embodied remembering. In The Routledge Handbook of Embodied Cognition. Routledge, 315–325.
[42] The Institute for Government. 2021. Timeline of UK government coronavirus lockdowns and restrictions. The Institute for Government. Retrieved September 15, 2022 from https://www.instituteforgovernment.org.uk/charts/uk-government-coronavirus-lockdowns
[43] Trello. 2022. About Us: Trello History, Logos & Customers | Trello. Retrieved August 12, 2022 from https://trello.com/en/about
[44] Zeba Siddiqui and Krishna Das. India to ease lockdown rules as coronavirus case numbers decline | Reuters. Retrieved September 15, 2022 from https://www.reuters.com/world/india/india-ease-lockdown-rules-coronavirus-case-numbers-decline-2021-06-06/
[45] Jan Zekveld, Saskia Bakker, Annemarie Zijlema, and Elise van den Hoven. 2017. Wobble: Shaping Unobtrusive Reminders for Prospective Memories in the Home Context. In Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction, 31–35. https://doi.org/10.1145/3024969.3024984
[46] Qiushi Zhou, Andrew Irlitti, Difeng Yu, Jorge Goncalves, and Eduardo Velloso. 2022. Movement Guidance Using a Mixed Reality Mirror. In Designing Interactive Systems Conference (DIS '22), 821–834. https://doi.org/10.1145/3532106.3533466
[47] 2022. Coronavirus closures: Map of where US states are tightening restrictions. USA Today. Retrieved September 15, 2022 from https://www.usatoday.com/storytelling/coronavirus-reopening-america-map/
[48] A Collaborative Digital Whiteboard for Teams | Miro. https://miro.com/. Retrieved May 11, 2023 from https://miro.com/whiteboard/