

Can a Technology Teach Meditation? Experiencing the EEG Headband InteraXon Muse as a Meditation Guide

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Abstract— Mobile and wearable technology now offers new avenues for technology-supported meditation practice and learning. Through a qualitative-dominant convergent parallel design, this study explored new empirical findings on the human perception of such technology-guided meditation training. A purposive sample of six participants trialled the device in several sessions during three weeks. Post-use, they commend the device for prompting self-guided learning. They highlight the importance of personalisation and adaptivity in educational technology, befitting Western pedagogical thought. Though these are guiding principles in current technology development, as they are believed to improve learning efficiency, they also prove crucial to user satisfaction and continued use of these technologies of the self.

Keywords—EEG headbands, meditation, technology, qualitative, human-technology relationship

1 Introduction

Electroencephalography, or its materialisation as an electroencephalogram (EEG), is a non-invasive method of monitoring and recording brain activity. Commercial EEG headbands will incorporate wearable technology (typically to placed on or around your head), which has brain sensors, critical points where the hardware needs to be directly on the skin. These sensors will register small electrical fields generated by groups of neurons during brain activity.

This study provides new empirical material on the use of the EEG headbands for meditation training. The commercial availability of this innovative technology is recent, with retail prices of market leader products typically much lower than the leading products in popular consumer technology such as tablets or smartphones.

The InteraXon Muse, or the ‘Muse Brain Sensing Headband’, provides such EEG technology for meditation. The company developed the headband technology initially for purposes other than meditation, but decided on this route as the best way forward

for commercialisation [1]. Since the Muse's entry to the market in 2014, the company has attracted over \$19 million in investments, doubling its revenues every year from its initial \$3.5 million in the first few months of release [2].

A structured series of sessions initially guides the user through the functionalities of the device in an incremental way, while the proposed meditation tasks become progressively more complex. One of its unique selling points is the live feedback of the weather soundscapes: in each session, live data on the user's brain activity is exchanged via Bluetooth with an app on that person's phone or tablet. With the data, the app determines if that person is in a meditative state, or not. A distinctive feature is the sound effect of tweeting birds when a calm focus is achieved. If distracted, the user hears rain coming down louder, signalling a need to re-focus. The live feedback throughout the session does allow innovative avenues for self-regulation during learning. After the session, the app generates a graph summarising the fluctuations between a calm, neutral and active mind throughout the session. The app awards 'calm points': one point for every second of 'neutral', three for every second of 'calm' brain states. 'Recoveries' are celebrated too, which is every moment moving from an active mind back to neutral. Further awards can be earned for high calm times, long session lengths, and so on.

There have only been a limited number of studies concerned with the effects of mobile or wearable technology for technology-supported mindfulness or meditation practice (such as [3]), though this is rapidly growing. Though small-scale, this study contributes to the intellectual agenda for human-technology relationship research in that it provides new empirical findings on the human perception of technology-guided meditation training.

This technology materially presents the claim that technology can guide people to learn something as characteristically human as meditation.

(1) Can we, as human beings, accept this proposition?

(2) Does actual experience with the device alter those pre-use perceptions?

The first question brings us to a core premise of human life (as believing that a technology can teach us something which is human would yield tremendous perceived power to the future teaching potential of technology). The second question investigates if experience with this particular device somehow influences or changes individual preconceptions.

2 Method

2.1 Approach and Design

This study opted for a predominantly qualitative approach, with exploration and discovery as guiding principles. Though this is not a phenomenological study, some of the researcher's theoretical biases are inclined that way. The foundation of the approach is a dominant interest in 'understanding the lived experience of other people and the meaning they make of that experience' [4]. For example [5], a qualitative

study to explore whether the Sonic Cradle, an interactive sound chamber, can successfully encourage users to have (perceived) meditative experiences. For this, they used semi-structured interviews, systematic coding, and descriptive conclusions to capture common subjectivities.

Unlike quantitative approaches, qualitative research often depends on a more interpretive design. This is part of a well-known critique around the subjectivity of qualitative research. Michael Patton [6] suggests using a comprehensive and integrated triangulation model called ‘The Rigor Attribute Model’, initially developed by [7], to ensure a high quality analytical process. It is a model of assessment along eight dimensions or ‘rigor attributes’ to determine whether the analysis is ‘High-Rigor’ (HR) or Low-Rigor (LR).

1. **Hypothesis Exploration:** whether a study has only performed minimal weighting of alternatives (LR) or dynamically reviewed multiple hypotheses and a broadening of explanation beyond the initial framing (HR).

This study was exploratory and therefore not testing hypotheses as such, but the emergent and iterative nature of qualitative research was an integrated part of the structured analytical steps explained in 2.5 Procedure.

2. **Information Search:** whether a study has only included routine or readily available data sources, such as through convenience sampling (LR) or has used purposeful sampling to comprehensively explore inquiry-specific data (HR).

This study has used purposive sampling specifically relevant to the inquiry.

3. **Information Validation:** whether information was accepted at face value or using poorly tracked original data (LR) or whether a study systematically corroborated and cross-validated information through triangulation and/or sampling (HR).

This study is information-rich in that it has three different data sets for cross-validation and triangulation, converging during the process of analysis.

4. **Stance Analysis:** whether nothing was done in regards to participant bias (LR) or whether data and participants were contextualised to provide a background to the information they provide (HR).

This study incorporated contextualisation in its design, as the pre-interviews gathered relevant background information on the participant’s relation to technology and meditation more generally, their individual habits and preferences, and attitudes to teaching.

5. **Sensitivity Analysis:** an emphasis on face validity and surface-level explanations (LR), or an assessment of the implications which is more strategic and systematic, which includes a consideration for the assumptions, limitations, supporting sources or problematic findings (HR).

This paper initially discusses the findings at a level close to the data and individual participants, and then moves to the ‘bigger-picture’ discussion of the implications, limitations, tensions, and more.

6. **Specialist Collaboration:** whether a study has not engaged independent, external expertise or peer review before reporting (LR) or whether it did incorporate such key expertise (HR).

Pre-publication, this study was proofread and reviewed by an international and widely published expert on technology acceptance.

7. **Information Synthesis:** whether the analysis is simply reported in a sequential form with little or no synthesis or integration (LR) or whether an analysis has ‘dug deeper’ in line with interpretive design, and presented integrated information with a thorough consideration for diverse interpretations, noting both consistencies in the data as well as tension points (HR).

This discussion of the findings follows a pattern which weaves participants together through an integrated narrative, with specific attention to their individual similarities and differences in experience and interpretation.

8. **Explanation Critique:** whether little or no use was made by other analysts (LR) or whether different perspectives were put to use, help explain, distinguish a chain of reasoning, or examine findings (HR).

This study was of a sufficiently small scale to be executed by one person rather than a research team, but references to other relevant research and literature are included throughout to examine and explain findings. Participants were also invited to comment pre-publication on the final draft of this article.

In regards to Information Validation above, [8] recommend ‘convergent parallel design’ as a term to describe where different data is collected in the same space of research, and in a relatively brief time. The ‘convergence’ refers to the merging of the separate results of analysis into one interpretation and conclusion. Other established authors use related terminology in their typologies, such as a ‘parallel mixed design’ [9], a ‘qualitative dominant’ study [10], considering the combination of data and weight of analysis, or a ‘partially mixed concurrent dominant status design’ [11].

2.2 Pilot

A pilot study with six participants preceded the execution of research and findings presented in this paper, as a best practice technique for rigour in empirical research. The pilot was near-identical to the final project, apart from two main changes. Firstly, participant sessions were video recorded in the pilot which did not yield any discussion-worthy data, so this was omitted in the final project. Secondly, participants initially used the device in a controlled experiment setting, whereas in the final project, participants were allowed to take the device to a setting that was comfortable and familiar to them (like their home). Some participants in the pilot recommended this to allow full immersion in the use of the device. This did lend greater authenticity to the experience of the device for personal use, which some of the session forms (see 2.4 Data) evidenced.

2.3 Sample

In this case, the study purposefully recruited young adults (aged 21 or 22) who had undertaken several years of formal higher education to become teachers, as this adds

an explicit framework to their perception of the Muse as a meditation guide. They are within the product's customer market, though they have never used the device before, or even heard about it. They are open to meditative practice, though have no or zero previous experience with any form of meditating training, technology-aided or otherwise. Participants self-reported to be part of a healthy population (i.e. no diagnoses of mental ill health issues). Both this and the previous factor have been identified as important to mindfulness research [12]. Participants were recruited by an independent project assistant, who did not conduct any of the interviews, as guidance on qualitative research [13] has pointed out the unrecorded researcher-participant interactions prior to formal data collection can actually impact on the findings.

Purposive/purposeful sampling focuses on depth of information generated by specific cases, and for that reason, it is typically small: usually 30 or less [14]. In a meta-review on this topic [15] analysed the 11 most-cited phenomenological studies in education & health sciences, which had sample sizes ranging from 8 to 31. Other guidance [16] has stated between 5 and 20. The number of interviews, rather than participants, has been used as an indicative measure as well. The sample here consists of 6 participants, preceded by a pilot study with 6 unrelated individuals. Each did 2 interviews, totalling 12 interviews represented in this paper, with additional data as further outlined below. For phenomenological studies, 5 to 25 interviews has been suggested as sufficient [17]. It must be noted, however, that while these numbers are offered as a general rule of thumb, there is often little empirical or theoretical argument as to the 'why' of these numbers. Given the available resources and study objectives, the size of the participant group and amount of data collected in this project are appropriate and at its full capacity. In line with Patton's pragmatic suggestions, [18] also argues the sample size depends on 'the quality of data, the scope of the study, the nature of the topic, the amount of useful information obtained from each participant, the number of interviews per participant, the use of shadowed data, and the qualitative method and study design used.' Repeat engagement with participants, as is the case here, is also presumed to mean a smaller amount of total participants is needed [19]. Again, the current project proposal can demonstrate to be on the small side but sufficient for all of the above indicators.

2.4 Data

Each participant was given the choice between completing two or four sessions with the headband. A 'session' is a guided meditation exercise using the headband for a minimum of ten minutes, up to thirty minutes. Only two participants chose to stop after the second session, whereas all others completed four sessions. This generated three data sets: interviews (12 in total of 20 to 30 minute duration), pre- and post-session forms (40 in total), and app data reports (20 in total). The interviews form the primary data set, with the forms and app data providing supplementary data to support or contrast findings from the interview analysis.

(1) Interviews - Before their first session, participants would be invited to a 30-minute pre-use interview (as further outlined in '2.5 Procedure'). After their last session, another interview would take place to actively reflect with the participant on the

whole experience, consider pre-use views, and co-interpret patterns of change where they occurred. These interviews lasted 20 to 25 minutes on average. They were semi-structured, with appropriate techniques of listening, prompting, and establishing rapport deployed.

(2) **Session Forms** - Before and after each session, participants would complete a self-reflection form with four open-ended questions. This helps contextualise whether their immediate post-use reflection aligns with the retrospective interpretation given in the post-interview, and enrich the other data sets with session-specifics.

(3) **App Data** - With each use, the app generates a report for the user which allows them to see the overview of the session: how many moments of distraction, how many 'birds', etc. It is displayed in a graph and recorded. This forms a minimal set of quantitative data used in this project to juxtapose with the participant's narrated experience in the post-interview, and post-session forms. (App data may for example show tensions in what actually happened with the participant's recollection of the experience.)

2.5 Procedure

Participants were aware that they would be using a technology for meditation in this project, though they did not see or know about the device before its first use. They were told about the expectations for their participation in the study, at which point they were asked to provide their informed consent in writing (or decline further participation, which none of them did). The data gathering tools used in this study are common and ethical, while EEG headbands are in themselves non-invasive devices. Participants had the right to opt out throughout the research. Internal ethical approval was obtained in full before the start of research.

A semi-structured interview proceeded based on a core set of questions. All participants were asked all of these questions, though they occurred in an order natural to the conversation, and were enriched with follow-up questions as appropriate to the responses given. Patton's guidance [20] on questioning was followed closely. They would then take the device with the login details as provided, download the app on a personal device, and proceed with using the headband for 2 or 4 sessions. They could self-determine the place and time for the session. On average, participants did a session every 4 to 6 days. Everyone completed within 21 days. Each participant completed a self-reflection form before and after each session, collected by an independent research assistant. The participant then returned after the last session for the post-interview with the lead investigator, which proceeded in a manner identical to the pre-interview.

In terms of the analytical procedure, the following steps were observed:

1. Transcribe pre-interviews one-by-one
During each transcription: active note-taking on emerging insights and analysis
2. Resting the data
3. Re-read pre-interview, with note-taking on emerging insights and analysis
4. Compare these notes with the ones made during the initial transcription
5. Transcribe post-interview, as in step 1

6. Thematic coding in NVivo using the Five-Level QDA Method [21]
7. Juxtaposition of Findings with the Supplementary Data Sets
 - a. Session forms – read and analysed per session across the participants
 - b. App data – accessed and analysed per participant across sessions
8. Integrated Report of Analysis
9. Member and Expert Check

Step 1 (and 5) was a manual transcription of the interviews into a written format. Transcribing is not just transferring audio to written symbols, it is already an active making sense of the data. Embracing this analytical view, transcription was parallel to note-taking in separate documents attached to the transcription files. The notes represent interpretations of certain sections, highlight what seemed to stand out as key data, and pick on specific points of interest to revisit later. The pre-interviews were first transcribed, and then individually reread before transcribing that participant's post-interview. So the analysis during the post-interview transcript was similar to the pre-interview transcript (i.e. active note-taking, interpretation and analysis) but additionally took into account the pre-interview data and preliminary insights drawn from there.

In **step two**, a few weeks were allowed in between transcription of the pre- and post-interview data. This 'resting' of data analysis helps to regain a fresh perspective, and upon resuming the analysis, see if the same sections stand out as important, the same emerging insight present themselves upon revisiting the data. It enhances validity of findings not to rush a particular interpretation, but to repeat the analysis and compare notes with the initial round, as one potential way to mediate initial assumptions or interpretations. This can only be done if sufficient time has been allowed for the 'resting' phase, unless multiple researchers are involved.

Then, in **step six**, the transcripts were further analysed with NVivo using the Five-Level QDA Method (Qualitative Data Analysis) [21], which is an iterative procedure. Initial codes emerged from step 1 to 5, while further codes were developed during step 6 and 7. Most codes were emergent allowing for inductive analysis, though not all. The act of coding requires revisiting the particularities of each interview, while building towards thematisation. For this, Seidman's guidelines on making and analysing thematic connections were followed [22]. Themes do not necessarily constitute unanimity of experience, but can capture variability. The thematic organisation allows for a structured discussion of findings, as presented in the next section. That composition should again be recognised as an act of interpretation in qualitative research in itself [23]. Insights were then juxtaposed to the self-reflection forms and the app data, per individual participant, in **step seven**. The report presented here has presented those integrated findings, highlighting in particular where contrasting material occurred. Though member checking is not without its critique, the paper was shared with the participants pre-publication and they were invited to comment or input further on the analysis and presentation of results. All participant identifiers were anonymised by assigning unrelated names (by a random name generator).

3 Findings

3.1 Pre-Use : Attitudes to Technology and Meditation

The participants' attitudes to technology in general were very diverse. Lucy states she 'wouldn't be able to live without it' (Intv 1/a/09:41), and Jenny confesses to be 'addicted' to her phone: 'it pretty much runs my life' (Intv 2/a/16:52). She feels comfortable with this high level of reliance. In contrast, Martha feels technology is necessary but altogether undesirable: 'weirdly I hate technology but I always go for the easy option' (Intv 5/a/10:36).

Though none of the participants had much direct experience with meditative practices, they had some indirect sense of what it might entail. Grinning, Lucy defines it as 'kind of uh way of destressing um you see it a lot on TV shows which are very like 21st century kind of um [1 second pause] don't want to say the word hippie but almost like very open-minded and things like that' (Intv 1/a/01:07). Another participant, Alex, actually describes her family background as 'kind of like a hippie family' (Intv 6/a/02:39), in a light-hearted manner. However, she has never connected the idea of meditation with technology before. In general, she feels technology is useful but says 'I can cope without it' (Intv 6/a/14:27). Debra expresses a similar feeling, in that she perceives technology as useful, as long as people don't become over-reliant, and maintain a healthy balance – in contrast to Jenny as stated above. To Debra, meditation is about 'calming your brain' and 'controlling your thinking' (Intv 4/a/05:46). She has used the Headspace app and this has been her only experience of meditative learning, and she experienced it as positive but didn't continue beyond its free content. The Headspace app is also Jack's only experience of meditative learning, but he says: 'I had a go and then got bored, so I stopped' (Intv 3/a/1:57). This is also very similar to Martha's experience with the app. All participants do believe meditation is a skill that can be learned with good guidance, though individual views differ as to whether it would be personally suited to them.

3.2 Pre-Use : Attitudes to Learning Meditation with the Muse

According to the participants, teachers are equipped with a host of special skills and characteristics, measured by high standards and expectations. Teachers need to be inclusive (Intv 1/a, Intv 4/a) as well as approachable, kind and caring (Intv 6/a), emotionally intelligent and responsive (Intv 2/a), encouraging (Intv 3/a), creative, engaging, enthusiastic and passionate (Intv 4/a), apt at building relationships (Intv 1/a, Intv 4/a) with a student- or child-centred approach (Intv 1/a, Intv 4/a). These pedagogical beliefs are in keep with modern, Western educational thought – which is unsurprising given their educational background. While none of the participants had used the Muse before, they were also hardly aware of the device and its functionalities. They struggled to picture what it might be like. They did have some ideas of a narrating voice (Intv 1/a, Intv 2/a) as well some sort of glasses showing certain images (Intv 1/a/08:04). Something simple: 'it needs to be like button, go' (Intv 6/a/10:34) as well

as discrete, not ‘like some sort of alien headset [...] like you can shove it under a pillow so you don’t look insane’ (Intv 6/a/11:09).

They mostly expressed positive expectations towards the potential of the technology, which they have not used before and know little about, to teach meditation. Their pre-use beliefs on whether a technology could teach meditation range from a confident ‘I don’t see why not’ (Intv 2/a/07:21) to a more cautious ‘just doesn’t seem like a match made in heaven really’ (Intv 5/a/04:13).

R can you still learn the same way

P yeah

R as you would from a human being?

P I’m sure you can. I think I mean maybe the world is leading in that way where you’re so much more technology-focused that that might be the future, you’re learning from technology.

R yeah

P If you don’t know any different, that we’re learning meditation from technology, if we didn’t have if we’d never been taught meditation through an actual person it wouldn’t make any difference, we probably wouldn’t know what we’re what we would have been getting different if it was a person

(Intv 1/a/16:42-17:11. R: Researcher, P: Participant Lucy)

3.3 Post-Use: Attitudes to Learning Meditation with the Muse

Post-use, participants express much more nuanced views. All participants do express a post-use interpretation that the device is expensive and sophisticated (despite being factually cheaper than their smartphones). However, due to frustrations outlined in 3.6 below, not all would pay its actual price for continued use.

Martha was arguably the greatest sceptic pre-use, and post-use does conclude that ‘human-led meditation instruction is a bit more natural’ (Intv 5/b/after 7:45). She somewhat dismissively describes her experience as ‘a little bit like virtual reality’ (09:34) and adds that it was ‘a bit um creepy’ (10:52) in feeling that the device was reading brain activity. Of all participants, she spent the least amount of time with the device, completing in only 4 days. By contrast, Jack completed his 4 sessions over 20 days, longer than anyone else, and concludes ‘I liked the technology actually a lot more than I thought I would’ (Intv 3/b/05:12). On their pre-session forms before the first session (which is their first encounter with the device), Jack and Martha interestingly express sentiments different to what one could expect from the final result. Jack writes that he is ‘slightly apprehensive, [it] looks a bit scary’ (P3-S1a) and Martha writes ‘Looks like something out of *Tron*. I am almost excited to put it on.’ (P5-S1a)

Lucy, who was very optimistic pre-use, did experience the use of the headband as positive and follows Jack closely by completing her 4 sessions in 19 days, though scoring significantly less ‘Muse points’ than him (3052, vs 4350), indicating Jack

achieved longer ‘states of calm’ according to the device. Lucy states she trusted the device, and feels there were clear moments of learning, including a changed perception of meditation. She experienced her sessions largely as positive, and relates this to a growing comfort in the human-technology relationship. After her fourth session, she writes: ‘I have learnt to trust the technology and let myself be taken over by it in the session’, and feels this affects her learning in a good way (P1-4b). In her view, the technology made meditation ‘more relatable and accessible’ (Intv 1/b/05:03). But she says, ‘I’m not sure the technology was actually teaching me to meditate or was more facilitating my teaching of myself’ (Intv 1/b/15:10). She goes on to explain the technology is useful to ‘kickstart’ a process of self-reflection as a learner.

Jack feels the same: ‘it’s not necessarily explicitly teaching you how to meditate but it’s helping you realise by yourself how to meditate’ (Intv 3/b/04:40). Despite Alex’s frustrations, she expresses a similar sense that the technology is useful to prompt greater self-awareness: ‘I think it made me more aware of what I was like how distracted I can get it made me aware of different things I wasn’t aware of before about myself’ (Intv 6/b/12:25), and a bit later: ‘I wouldn’t say it taught me how to meditate but it taught me how it made me reflect like made me more self-aware’ (about 15:00). Jenny says the same: ‘I guess in a different way it actually teaches you to self-evaluate yourself? And to self-assess and to say actually no, I’m not at that stage, I need to go back and that in itself is quite powerful because make sure you’re in touch with your own body and what you’re feeling for yourself’ (Intv 2/b/09:50). In a sense, the participants are actively validating the device’s educational potential through finding a fitting place for it in their taught pedagogical framework.

3.4 Post-use: Human vs Technology

For Jack, the post-session data was a highlight of his experience (Intv 3/b). To him, that functionality was a key reason to continue meditation with the device. ‘I think the yeah the feedback that this can give would be better than a human teacher can give’ (Intv 3/b/25:02). This is in sharp contrast with his pre-use claim that no technology could ever be better than human teaching (Intv 3/a/17:45).

Both Jenny and Debra started with a positive predisposition towards the idea of learning to meditate with technology, but both conclude, in Debra’s words: ‘I didn’t feel like it was teaching me anything’ (Intv 4/b/02:24), and later on explains: ‘I felt more stressed than before I had done them because I just listened to heavy rain [laughs] for the whole session um which actually doesn’t make you feel very good about yourself because you’re like ‘oh I’m not very good at this’ (Intv 4/b/08:15). However, Debra scored most ‘Muse points’ of all participants (4853, just over 500 more than the runner-up, Jack), and most ‘birds’ (204, which is 75 more than Jack). So according to the app’s data, and in contrast with her personal view, she did better than everyone else. Her first two sessions were in that sense significantly more successful than the final two, however, which may influence her retrospective evaluation overall in the post-interview.

While Jenny and Debra share some of their views, Jenny is still open to meditation practice with technology, but Debra expresses a clear preference for human teaching, which she aligns closely to a polar nature/technology discourse:

P I I don't think that technology is as useful as a person [chuckles] um but like I said the headspace app I've found that was useful

R hm-mh

P but that was a recording of a person

R hm-mh

P who was doing a meditation lesson with you

R hm-mh

P so actually that's still kind of human in a sense

R yeah

P because it's just a recording and you're you're taking part in the lesson but from home or um but

R but you have different feelings about this technology right?

P hm-mh I just found it the woman was like a robot [chuckles] and every session she was pretty much telling me the same instructions

R yeah

P um

R like a robot

P like a robot it wasn't any different each week um yeah and it just felt more kind of tech-y you know with the data and the graphs and all the different pages on the app

R yeah

P um having to wear a band round your head

R yeah

P it just didn't it wasn't as natural and [1 second pause] like meditation is meant to be natural, you can go outside if you want, it's meant to be about connecting and with yourself and the world

R and did you feel like this distanced you more rather than

P yeah it didn't connect you you just you sat in a your room and you put a metal band round your head [chuckles] and you listen to rain

R yeah

P but it wasn't natural rain was it it was a it was a [1 second pause] fake recording of rain [chuckles]

R yeah

P um it just didn't feel it didn't feel natural at all or human I would say it felt very tech-y

(Intv 4/b/13:39-15:23. R: Researcher, P: Participant Debra)

Similarly, Alex still feels the 'divide' between technology and meditation which she articulated pre-use. Her post-session forms consistently express her sense of difference between her personal (non-technology) preference and the use of the device. She experienced the electronics as highly distracting and annoying (including the

headband itself, the phone, the female narrator, the birds, and the rain). If anything, she says, the perception of that division has grown stronger: 'I thought it I was wondering whether it would like turn me to 'the other side' [grins] see if I would but clearly not' (Intv 6/b/11:49). However, the rejection isn't absolute. Several participants feel that rejecting the device for themselves doesn't mean rejecting the teaching potential entirely: 'I think it I think it definitely has potential to teach others like I know what I know but I think there's people I know that would benefit from it' (Intv 6/b/19:02). Equally, Debra praises the Headspace app as a technology for meditation practice (Intv 4/b).

Despite her personal frustration with it, Jenny concludes 'I do think that it would be able to teach you' (Intv 2/b/25:21) and continues: 'it is the right teacher with the right learner and that is actually sometimes what happens even with humans because someone may not click with a human and that actually tells you it will teach them better than the human will so'. She feels that 'the optimum would probably be a combination of both um [4 second pause] I don't [sighs] I don't know they're just so different' (25:00). But even Martha, who swiftly rejected the device for herself, concedes: 'I think for someone if someone had never meditated before I think it would teach them well' (Intv 5/b/03:29).

3.5 Post-Use: Moments of Learning

Moments of learning occur in the form of self-reflection and self-understanding. After her first session, Lucy writes: 'I'm not sure I've learnt how to meditate because clearly I couldn't do it but I learnt about myself instead!' (P1-S1b) and though a different insight, Jack writes after his first session that he is 'Better at sitting still and being calm than I thought!' (P3-S1b). This is pertinent because he emphasised in the pre-interview that 'sitting still' was difficult for him, and he associated this closely with meditation practice. He saw meditation as 'chilling out by yourself and clearing your head' (Intv 3/a/14:55) and after using the device, he states (without prompting) 'one of the things that this has taught me is maybe like meditating is absolutely a lot more to it than sitting still which is a preconception I had' (Intv 3/b/1:44), explaining further that 'it's very much an active process which I hadn't really considered it to be' (03:20).

Jenny, Martha and Debra, who did not enjoy their experience overall (despite objective successes shown in the app data), also do not feel they have developed their pre-use understanding of meditation. But Alex does express a learning process of that nature: 'I think I realised meditation is different to that everyone I was like in my head that wasn't meditation to just stay calm and focus on your breath and that's it. To me it would be reflecting on something I think yeah like reflecting on one point and just kind of like or like something like patience or something and just kind of like having kind of like small thoughts about it but I wouldn't consider meditation in my eyes to be complete silence not thinking about anything and just being like because I think I get so distracted which I've learned' (Intv 6/b/05:48-06:22). Later on, she adds that she feels that the device was 'trying to teach me meditation just kind of like monk-style just like silent and nothing and just kind of like sitting there doing noth-

ing really' (Intv 6/b/14:03), which conflicts with her personal definition of meditation – and is the opposite of Jack's insights.

Despite her positive predisposition to technology, Jenny's experience with the device was highly frustrating, in her words: 'I literally just wanted to throw it across the room' (Intv 2/b/15:15), even though the app data shows relative success in achieving calm states in comparison to other participant results. She reattributes this to herself: 'potentially like my fault not technology's fault I would say like there's a good chance it is more my fault' (Intv 2/b/8:59). This expresses an interesting human-technology relationship, with the device being 'excused' for having to deal with flawed human users.

3.6 Post-use: Frustrations

Feelings of frustration across participants were directly related to three things: (1) the rain, (2) a mismatch between self-assessment and the soundscapes, and (3) a lack of personal adaptivity. This often went hand in hand with favouring human teaching above technology. Lucy for example states: 'it would be better with a human teacher cause then, they'd see that I wasn't there or that I was stressing or my shoulders were tense or something they can see the physical signs and then they can talk me through more strategies whereas the technology was very neutral so it just said "keep breathing" and I was getting more angry' (Intv 1/a/06:17). In his interview, Jack echoed exactly the same sentiment (Intv 3/b). Near the end of the interview, Lucy explains again that a human teacher would allow for personal feedback and co-constructive reflection and action on the results of learning, which is exactly what Debra and Jenny also express as the educational void. On her second post-session form, Jenny writes: 'I don't feel like I am learning to meditate because I still don't have a technique that works – it keeps telling me the same thing' and also 'When its getting hard and I am struggling to focus it does nothing to support me except rain harder which annoys me!! I don't look forward to using it.' (P2-S2b). Her app data does however indicate a 20% improvement in calm state from the first to the second session.

Debra got many birds in her first two sessions (90 and 107), but a lot of rain in the final two sessions, indicating distraction. The app data directly relates to her experience. She characterises her third session, for example, as 'bad. I didn't get any birds. :-(' (P4-S3b). After the final session, when she got only 7 birds, she writes 'meditation should be quiet.' (P4-S4b). She also retrospectively concludes: 'I don't feel I have learnt anything new from using the headband' (P4-S4b) even though on the first two post-session forms, when she got many birds, she does express learning. For example, after the second session, she wrote: 'Happy because I have improved' (P4-S2b). Retrospectively, she does not feel that the data accurately represents her performance and that this made her distrust the device (Intv 4/b). Jenny and Alex express the same 'mismatch' sentiments on their post-session forms.

While Jack likes the technology more than he thought he would, and states he would continue using it, he did find it equally distracting and annoying when the soundscapes did not match his self-assessment: 'like when I was getting distracted it showed me that I was distracted but there were times whenever I thought I felt that I

was calm, I felt that I was focused, and I wasn't hearing birds' (Intv 3/b/19:15). The same is true for Jenny and Martha. Nobody enjoyed the rain (though that is the function's intent), but for some participants like Jenny, it did cause a spiral ending in rejecting the device (Intv 2/b/3:15).

4 Discussion

4.1 Overall observations

The participants had never used the device itself, but were open to the idea that it could teach meditation ; ranging from very acceptant 'why not' attitudes, to more cautious willingness to try. They were of course aware that the project entailed the use of a technology for meditation, so they could have been influenced by that context in itself. Experienced meditators could perhaps feel differently, with a developed sense of what meditation entails.

As trainee teachers near-graduation, however, they do have very explicit and high expectations of good teaching. They name qualities such as empathy, creativity, kindness and care, enthusiasm and passion,... as key to good teaching. Post-use, they didn't report experiencing these as traits of the device, which is perhaps unsurprising. At the post-use stage, the technology's potential was commended as a 'catalyst' for learning, prompting self-assessment and self-reflection as valid tools for learning meditation. So a re-categorisation occurred of the device using their existing framework of pedagogical knowledge. In some cases, the device's functionality of feedback was considered better than human teaching. However, any sense of automated, robotic, or unresponsive human-technology interaction was a highly negative experience.

They did note strong feelings of frustration and distrust where the device's feedback did not match their inner self-assessment. Objectively recorded experiences with the Muse were less significant than subjective experiences and predispositions to technology in this sense. Of course, a human-led learning context could yield the same experience, for example when a student receives a test score which he or she doesn't feel reflects their true learning. There is a sense of unfairness to the experience, with a resulting disengagement with the context of learning. Teacher adaptivity was also brought forward as key to sustained learning, in that a teacher can pause to explain why something is happening, or give personalised tips, or moments of encouragement if it's getting difficult, or discuss individual progress and tailor subsequent activities,... They were disposed towards believing this adaptivity and personalisation is a normal technological possibility, and disappointed to encounter a one-size-fits-all model instead. Much current research and development in technology for education is building towards greater adaptivity and personalisation as it demonstrates higher learner gain. But aside from educational impact or effectiveness, these functionalities may be more important than anticipated to meet human expectations.

Participants state their moments of learning as, firstly, a developed understanding of what meditation is, and secondly, a greater understanding of their own habits and preferences. The latter underlines its potential as a self-reflection tool, for meditative

practice or otherwise. The former is perhaps unsurprising, as the participants started with very little prior knowledge of meditation, other than assumptions or indirect information, and therefore whatever they experienced next would be an enrichment to the little direct knowledge they had pre-use. As a meditation guide, it would appear the device did teach its users something about meditation after all.

4.2 Limitations

Though the interview is a common and accepted data gathering tool in qualitative research, it is underpinned by the idea of ‘the modernist subject’ in Western thought [24]. We can never fully understand the Other, though phenomenology accepts that language and stories are pretty much as close as we can get to understanding the Other’s experiences, if we listen carefully and diligently. Reporting qualitative research findings has been likened to story-telling [25], which of course adds its own layer of meaning. Though an academic necessity, such as in writing this paper, it creates a further distancing from a more direct relation to the Other. Yet Seidman encourages researchers to be affirmative in their analysis: ‘you have mentally lived with and wrestled with the data’ [26]. Ethics in research is not only about data protection and confidentiality, but the integrity of the researcher in faithfully presenting findings with respect to the participant’s voice. The mechanisms of participative inquiry in the design of this study hopefully have enabled that further.

The participants in this study were from a Western, white background, and approach meditation as a secular, stress-reducing technique. Though this helps sample coherence, the field of research pertaining to this topic of study certainly requires more culturally and racially diverse participants, as for example found in [27]. Otherwise the sample in this study is of course small, but the rich data set did yield an interesting, diverse analysis. Larger samples could potentially afford a view on trends.

5 Conclusion

Before use, participants accepted the proposition that there was a technology which could teach them to meditate, with varying levels of enthusiasm and scepticism. After using the device, it was commended as a catalyst for self-guided meditation learning, prompting self-reflection through the meditation exercises provided. However, this study emphasises the importance of personalisation and adaptivity in educational technology, as the experience of an automated, unresponsive human-technology exchange is highly negative, and dramatically reduces the likelihood of continued use – especially for learning. Arguably this matches modern Western pedagogical thought for human-to-human education, but the human-technology relationship is held to those same principles. Active ‘human versus technology’ comparisons mediated the perception of the device before, during, and after use. Expectations of technical possibility are normalising a technology’s personal responsiveness as the new standard.

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