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Research Matters

Articles from the Pedagogic Research Conference 2018

— *Research Matters* —

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Published by Centre for Learning and Teaching
University of Brighton Press

First edition published 2019

ISBN: 978-1-910172-20-9

Available online at:
https://staff.brighton.ac.uk/clt/Pages/Research/publications.aspx

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Can fidgeting be used to measure student engagement in online learning tasks?

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Abstract

Fidgeting may be a way to monitor second-by-second student engagement, which would be especially useful for gauging and improving the effectiveness of online learning. This article is based on research that found less fidgeting during a formative online reading comprehension test indicated that students were more engaged.

Online formative assessments are effective facilitators of engagement, especially with intelligent tutoring systems. This research used two computerised, three-minute reading-comprehension tests, identical in all aspects except that one reading was boring and the other was interesting. These were presented to 27 healthy adult volunteers while alone in a classroom; the stimuli were combined with an interrupting clicking task that forces screen engagement. The participants' postural movements were measured using video-tracking, and these were compared to subjective ratings for ten visual analogue scales in a repeated measures design.

The interesting reading elicited less fidgeting shoulder movement than the boring reading. There was also a correlation between the ratings for wanting 'the experience to end earlier' and the extent of shoulder movement. The research also indicated that the context of formative online reading tests, the type of boredom elicited is restless rather than lethargic.

Keywords: Engagement, boredom, Non-instrumental Movement Inhibition (NIMI), fidgeting.

Introduction

This article reviews the strengths and weaknesses of using measurements of fidgeting as a metric for engagement during online learning tasks. Online learning tasks are associated with a range of special cognitive states called learning emotions. Engagement is one of the key cognitive states for learning during education. The rationale for measuring engagement objectively is to complement and verify traditional subjective measurements; physical measures also give useful moment-to-moment measurements without interruption of a task. Fidgeting is one of a class of non-instrumental movements that are inhibited when a person engages with a task. A variety of seated tasks in human-computer interaction have been shown to result in Non-Instrumental Movement Inhibition (NIMI). A number of experiments from our lab have clearly demonstrated that subjective engagement is linked with a measurable reduction in fidgeting.

Achievement emotions relating to learning and education

There are many different models of emotions and cognitive states. The most well-known are Russell's circumplex model with axes of valence and arousal (Russell, 1980), and Ekman's model of seven discrete basic emotions (happiness, sadness, fear, anger, disgust, surprise and contempt) (Ekman, 1999). Pekrun and colleagues have recognised that many of the basic emotions that Ekman highlighted are states that seem rarely relevant in the classroom, so they developed a model of achievement emotions that include: engagement, boredom, anger, hope, pride, enjoyment, hopelessness, anxiety and shame (Pekrun et al., 2006). In this structure, engagement is one of the key cognitive states for successful learning.

Engagement

Engagement is a cognitive state relevant to the applied psychologies including work psychology (Kahn, 1990; Macey and Schneider, 2008; Christian et al., 2011), educational psychology (Finn and Zimmer, 2012), positive psychology (Csikszentmihalyi, 1998), and human computer interaction (HCI) (Webster and Ho, 1997; O'Brien and Toms, 2010). Engagement is also important in human factors and ergonomics (for example, vigilance), experience design (both online and in the theatre), and in the emerging field of human-robot interaction. Each field has a different way to define and measure engagement, although all agree that engagement involves interaction and is in some way different from attention. Most definitions presume that usually engagement lasts longer than attention, engagement allows for some concurrent activity, and that engagement will have some influence on later behaviours.

Our group defines engagement as a family of related cognitive states geared toward extended interaction and/or a purposeful outcome, operationalised by a collection of behaviours, none of which are absolutely necessary at a given point in time, including: attendance, attention, memory, caring, emotion, taking action, making an effort, and (similar to the exclusion in attention) inhibition of irrelevant activities (Witchel, 2013a). The inhibition of irrelevant activities is explained as follows: when students engage with a lecture (a purposeful activity), they will inhibit irrelevant activities such as playing video games and talking to their friends, while pursuing appropriate activities such as watching the lecture and taking notes. The advantages of this definition of engagement are:

1) It includes negative feelings that result in continued interaction (for example, when a student intelligently but persistently disagrees with an instructor).
2) It focuses on measurable effects/outputs of engagement rather than mixing causes and effects, and thus avoids presupposing the causes of engagement.
3) It allows for a purposeful outcome without further extension (for example, the joy of a performing a chore well, without the desire to extend the chore).

The reason engagement is considered important is that it is understood to be a fundamental factor to many successful tasks performed by a person in a relationship with an organisation. It is assumed that a student who is supposed to learn in a school will have to engage with the school in order for the learning to take place. Likewise, it is presumed that an employee who is expected to perform a task will need to engage with their employment and employer in order for that task to be done correctly, and in a way that the task fits in with the larger product or service being delivered. In human-computer interaction, engagement is the primary factor being sought, whether the goal is to teach the end user or to advertise to them.

Measuring engagement

There have been many different ways demonstrated to measure the different types of engagement, usually being dependent upon the context of engagement; thus, there are checklists for student engagement (Finn and Zimmer, 2012), employee engagement (Kahn, 1990), and engagement with the internet (O'Brien and Toms, 2010). When judging the engagement of online interaction, many researchers have focused on blunt engagement metrics such as footfall, hits, or time on page (Witchel and Westling, 2013b); such metrics do not exclude situations when end users are not really engaged, such as when they load a page and then go away to get a coffee.

The opportunity to make objective (usually physical) measurements on end users addresses this issue. These objective measurements can include physiological measures (electrodermal responses or heart rate), deliberate behaviours (mouse activity), or non-instrumental behaviours (facial expressions, fidgeting). The main disadvantage to using these physical measures is that the measurement process and the analysis is usually performed on a single user at a time, and is often laborious. The demands of these measurements mean that they are often used as a complement to less laborious subjective measurements. Furthermore, the interpretation of the physical/objective measures is difficult and requires a conceptual model for explanation. Nevertheless, objective metrics have the advantage of being less subject to dissimulation or alteration for social purposes.

Posture and fidgeting

Posture is popularly associated with engagement, especially within human-computer interaction. It is sometimes suggested that there is a simple equivalence between approach and engagement; that is, people who are engaged with a computer (or a person) will lean forward, and when people disengage, they will lean back slightly (Sanghvi et al., 2011; Coan and Gottman, 2007). This idea is widely accepted among the general public (Pease and Pease, 2004). However, our team and others have sought and failed to find this association in situations where the end user is already sitting in a chair in front of a screen in a laboratory experiment (Witchel et al., 2016; Mota and Picard, 2003). One explanation for this lack of association is that forward-leaning, load-bearing postures, where the head rests on the hand(s), are usually associated with boredom, disengagement, or difficulty, despite the fact that these postures are usually linked to increased leaning forward compared to most other seated postures.

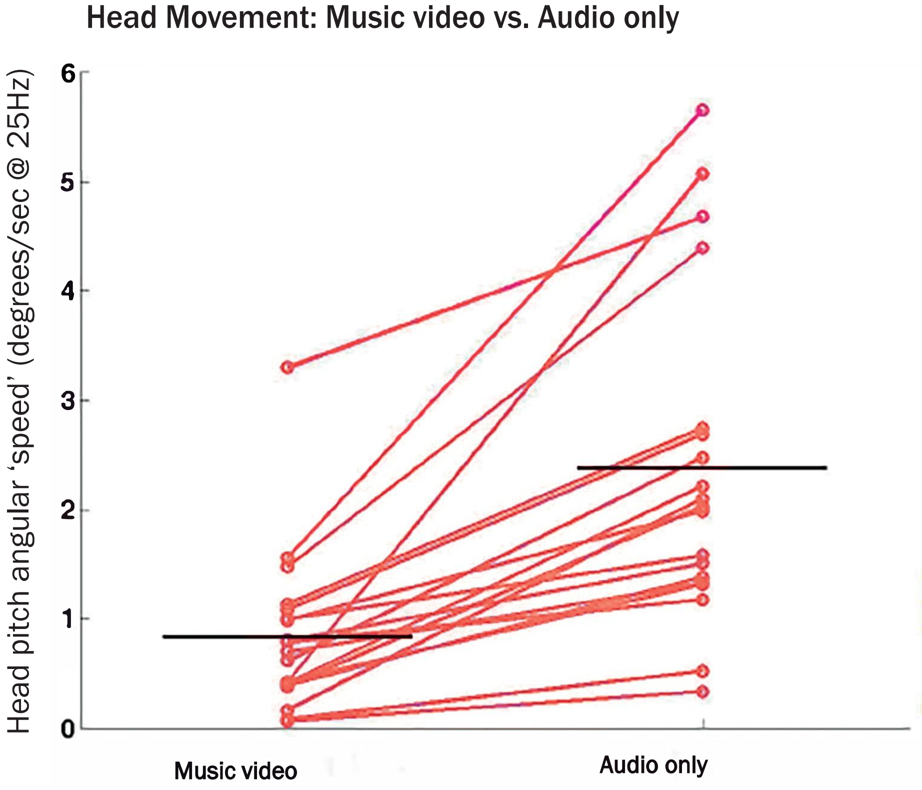

Figure 1. Head movement elicited by a music video vs. by the same audio track alone. Data adapted from Witchel et al., 2016.

By contrast, scientific study and statistical analysis has shown that boredom or disengagement is typically associated with increased movement, and thus engagement is associated with decreased movements (D'Mello et al., 2007; Grafsgaard et al., 2012; Witchel et al., 2016). We have shown that part of the reason for this is due to the requirements of a steady gaze (see Figure 1), but that further inhibition of non-instrumental movements occurs simply due to engagement, irrespective of gaze (see Table 1) (Witchel et al., 2016).

DISENGAGEMENT	WATCHFULNESS/VIGILANCE
Non-visual stimulus	Visual stimulus
Internal mentation	High content rate
Break-taking	Persistent new content
Boredom	Interest

Table 1. Causes of monitor disengagement and engagement

Movements can be functionally categorised as those that are part of the current deliberate task (instrumental movements) and those that are not (non-instrumental movements). Fidgeting is one of a class of non-instrumental movements (see Table 2, over), which are inhibited when a person engages with a task (Witchel et al., 2014). Fidgeting is also thought to be an explicit result of task unrelated thoughts, or mind wandering (Seli et al., 2014; Carriere et al., 2013). This is presumably due to the fact that thought is embodied, and that unstructured thought is reflected by unstructured movement that permits it (D'Mello et al., 2012).

INSTRUMENTAL	NON-INSTRUMENTAL

Explicit task movements
Implicit task movements
▪ Gaze (eye, head, shoulders) to see another part of the screen
  ▪ Rotate
  ▪ Lean in to see something small
  ▪ Controller (arm, shoulder)
	Comfort movements
	▪ Break-taking
	▪ Scratching
	Emotional expressions
	▪ Face touching
	▪ Self-adaptors
	Escape movements
	▪ Fidgeting

Table 2. Categorising movements that are typically observed during human-computer interaction. Examples of instrumental vs. non-instrumental movements.

Measuring movement as a surrogate for engagement or boredom

Movement can be measured in a variety of ways. In traditional psychology experiments movement was manually scored by trained observers (Bull, 1987). Precise measurements of specific movements can now be made by opto-electronic systems such as Vicon or the Microsoft Kinect depth sensor (Witchel et al., 2012; Grafsgaard et al., 2012). It was previously assumed that specific movements had specific meanings, although these meanings (other than for facial expressions) were difficult to specify. More broad measurements of total movement have been estimated by seat pad sensors (D'Mello et al., 2007; Seli et al., 2014), video tracking (Witchel et al., 2014) and wearable inertial sensors (Chalkley et al., 2017).

One difficulty in interpreting movement as disengagement is that certain types of instrumental movements are required by, or related to, the task (see Table 2). For example, in sports or dancing, greater engagement is linked to increased movement. By contrast, watching engaging videos on a screen will be linked with a type of rapt engagement that suppresses most movement (see Figure 2). The resulting measure-

	INTERESTED	BORED
Physically active	Dynamic engagement (Instrumental or entrained)	Restless
Physically still	Rapt engagement (e.g. NIMI)	Lethargic

Figure 2. Relating engagement and boredom to measurements of total movement. There are effectively two kinds of engagement (one with extensive bodily movement and the other without) and two kinds of boredom. In most human-computer interaction, the more common states are rapt engagement and restlessness.

ment ambiguity would be solved if there were an automated way to differentiate instrumental from non-instrumental movements by the quality of the movement (see Figure 3). Unfortunately, it is not currently possible to use the nature of the movement to recognise whether the movement is instrumental. To solve this issue, our group has designed interactive tasks and stimuli where almost all activity is by definition non-instrumental. For example, when listening to music while seated in a chair, literally all movement is

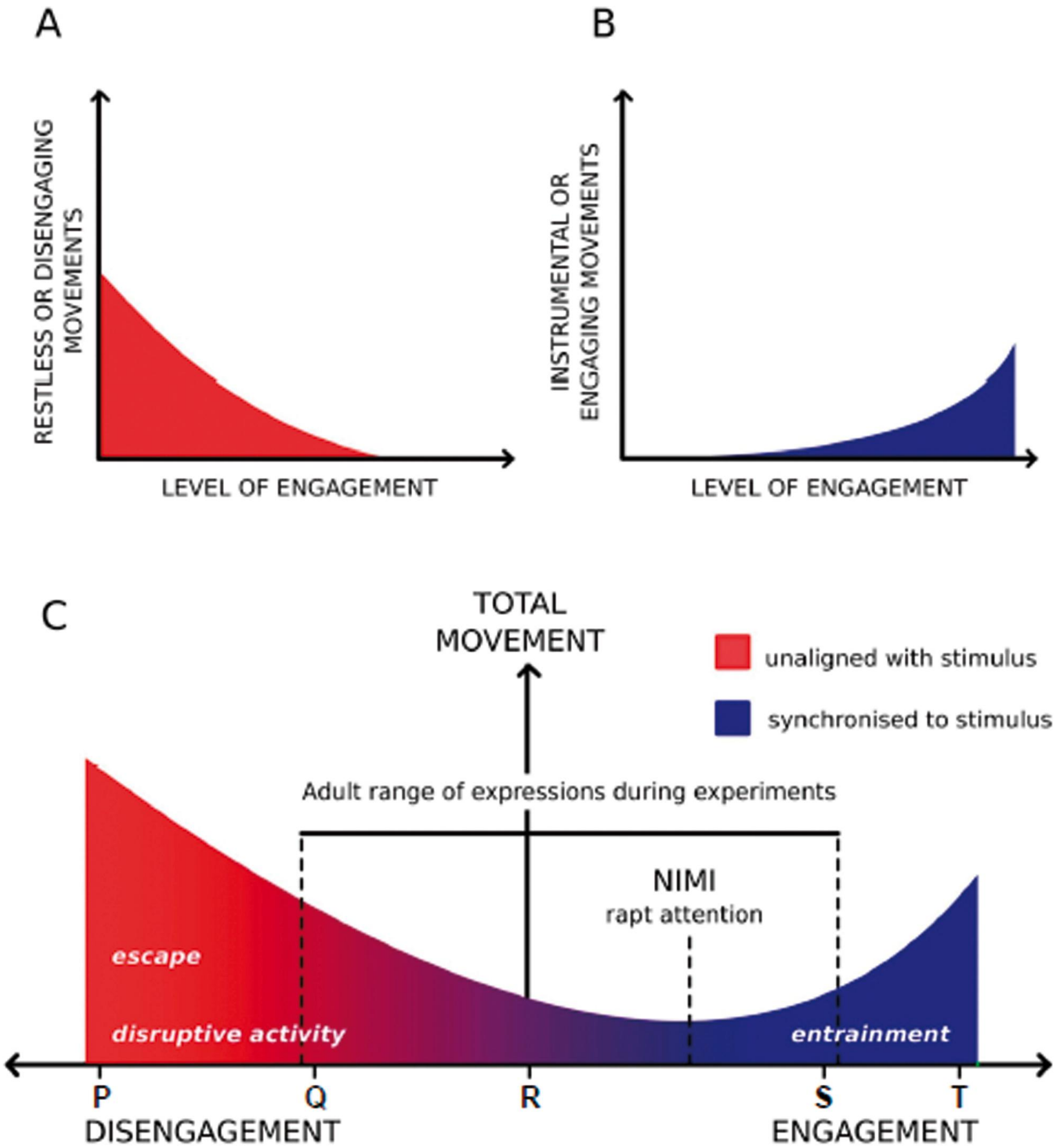

Figure 3. Total movement (curve, panel C) is the additive sum of two kinds of movement: non-instrumental movement (red, panel A) plus instrumental movement (blue panel B). Non-instrumental movement is not synchronised to the stimulus (i.e. its timing is self-generated and related to mind wandering). In panel C, the x-axis shows the comparative engagement of levels of different activities: P – running away from the stimulus, Q – fidgeting when bored by the stimulus, R – interested by an on-screen stimulus, S – engaged with an active on-screen stimulus such as a driving game with a steering wheel, and T – engaged with a physical (non-seated) task, such as dancing. Used with permission, Witchel et al., 2014a.

non-instrumental (Witchel et al., 2013c). Similarly, when a participant is watching a video, nearly all movement is non-instrumental except for head and eye movement associated with gaze (Witchel et al., 2014b). One methodological advance that our group has deployed is to make interactive stimuli that are controlled completely by a handheld trackball (as opposed to a mouse and keyboard); in these situations, the only instrumental movements (in addition to those linked with gaze) are thumb movements.

To precisely test whether engagement itself was affecting fidgeting, two nearly identical reading tasks were presented to 27 participants (in a counterbalanced order) (Witchel et al., 2016). The only difference between the tasks was that one reading was interesting (an excerpt from a best-selling novel) while the other excerpt was boring (regulations on banking by the European Union); note that these experiments were run over two years before the UK Brexit vote, when the EU was simply considered boring. Both tasks required participants to click a handheld trackball approximately every two seconds when a grey signal appeared on the screen (and temporarily interrupted the reading), in order to verify (with reaction times) that participants were maintaining their attention on the stimulus. Head movements (based on video analysis of the lateral aspect film) were calculated for each 180 second task (see Figure 4). The boring stimulus

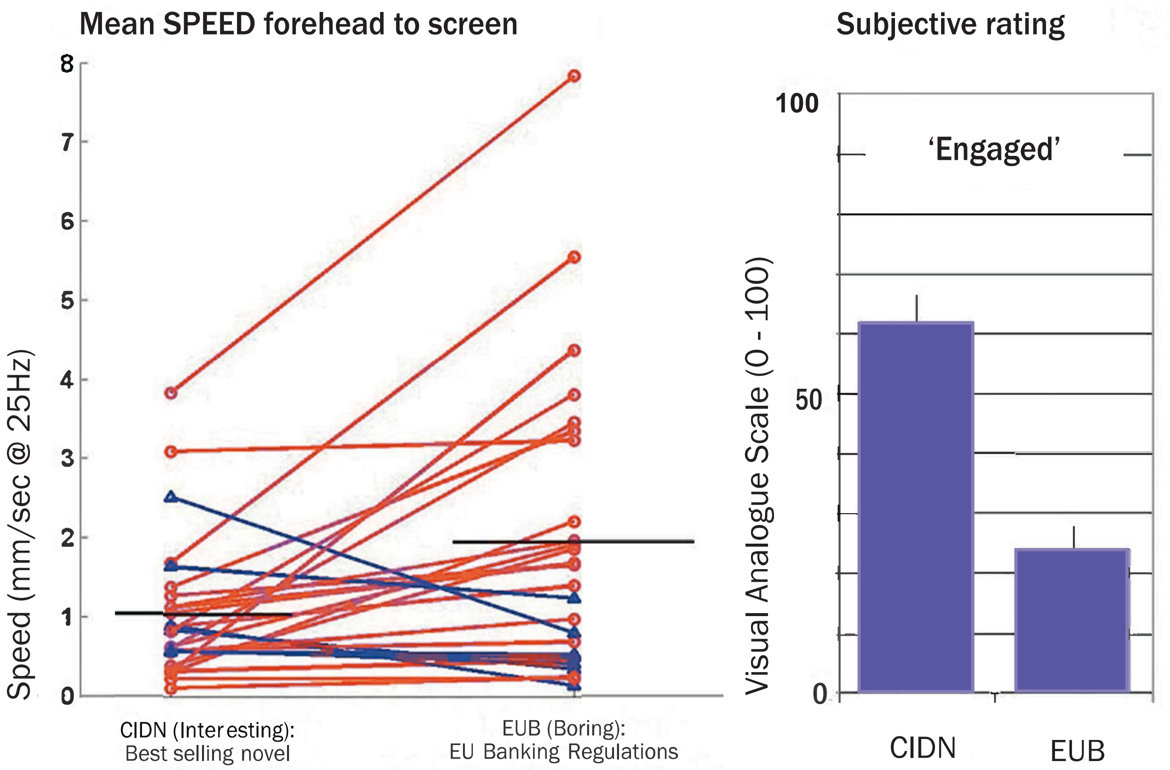

Figure 4. Engagement leads to decreased movement in comparable reading tasks. The panel at left shows the net head speed for two comparable on-screen reading tasks, where one task included interesting text (a best selling novel) while the other did not (EU banking regulations). Each pair of points with a line is a single participant who experienced both stimuli. The black horizontal lines are mean values. The panel at right shows the subjective ratings (mean ± s.e.m.[1]) of the two stimuli based on a visual analogue scale for 'I felt totally engaged'. (P < 0.05, ANOVA[2] with post hoc Tukey test). **Adapted from (Witchel et al., 2016).**

1 s.e.m: standard error of mean.

2 ANOVA: Analysis of variance, a statistical technique.

elicited approximately double the amount of movement as the interesting one. In the same experiments, thigh movement was also equally doubled by the boring stimulus, so the result is not simply a result of gaze stabilisation. This result is essentially identical to what was found 130 years earlier by Francis Galton, who observed listener's head movements while listening to a lecture, and found the same ratio in a comparison of when people were interested vs. bored (Galton, 1885).

Conclusion

Our team has found that 1) Proximity (mean distance to screen) is a poor metric for engagement, because bored people have a wide 'range' of positions. 2) Engagement is associated with NIMI. Thus, the most revealing postural measurement for understanding engagement is net movement, rather than position or distance from the screen. 3) Total thigh movement is more specific to boredom than total head movement because the head often moves instrumentally to maintain gaze. 4) Wrists and ankles also respond to engagement with NIMI, and they show a weaker difference than thigh measurements. Future efforts will focus on attempting to differentiate non-instrumental from instrumental movements based on the structure or timing of the movements.

Acknowledgements

We gratefully acknowledge the technical contributions of Michael Roberts, Jacob Greaves, Amy Moffat, and the administrative contributions of Chätrin Tolga and Terri Desmonds. We acknowledge funding received from The Wellcome Trust and Brighton and Sussex Medical School's Independent Research Programme. Finally, for the original idea on the science of movement, we acknowledge Harold Nicholas.

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