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Why do people sit? A framework for targeted behavior change

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ABSTRACT

To improve health and wellbeing, it is crucial that people regularly interrupt their sitting. In this paper, we propose a framework for examining and changing sitting behavior that addresses two key steps in the process towards developing effective interventions. First, we suggest that research should move away from its current focus on sitting time, which is an outcome of behavior. Rather, researchers should focus on stand-to-sit and sit-to-stand transitions, which are discrete units of behavior. Second, drawing on goal hierarchy models, we suggest that people rarely engage in stand-to-sit and sit-to-stand transitions for the purpose of being in a sitting or standing position; rather, we suggest that these transitions are means to higher-order goals (e.g., to complete work tasks, to watch television, to eat dinner). To improve adherence to and effectiveness of sitting behavior interventions, intervention designers should aim to increase the frequency of sit-to-stand (and stand-to-sit) transitions. To achieve this aim, intervention designers should capitalize on the higher-order goals that are typically served by these transitions. We suggest four concrete intervention strategies to increase sit-to-stand transitions in congruence with people's everyday goals. We also describe the implications of our framework for theory and methods in sitting behavior research.

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People in Western countries nowadays spend 8–11 hours per day sitting on average (Ekelund et al., 2019; Loyen et al., 2017). Yet, high levels of sedentary behavior are associated with serious physical and mental health problems, such as declined cognitive function, cardiovascular disease, and all-cause mortality (Biddle et al., 2016; Saunders et al., 2020). To improve health and wellbeing, it is crucial that people sit less and interrupt their sitting more often (Piercy, 2019). As such, a large stream of research has attempted to pinpoint the determinants of sitting behavior (Gaston et al., 2016; Prapavessis et al., 2015; Stierlin et al., 2015), and to develop and test interventions to help people limit their sitting time (Hutcheson et al., 2018; Memon et al., 2021; Stephenson et al., 2017). These studies have provided valuable insights into, for example, the different contexts in which people sit (Owen et al., 2011), and have yielded promising intervention techniques to change sitting behavior (Gardner, Smith, et al., 2016).

Yet, the research field of sitting behavior has largely overlooked two crucial steps in the process towards developing effective interventions (Bartholomew et al., 2006; Michie et al., 2014). First, in most prior sitting research, the target behavior of interest remains unspecified. What behavior or

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action related to sitting do researchers wish to understand, predict, or change? Most studies, whether focusing on quantifying, understanding, predicting, or changing sitting, have focused on 'sitting time'. However, the time spent sitting is not a behavior, but an outcome of behavior. Due to this ubiquitous focus on sitting time, the exact behavior that underlies people's sitting time – and that interventions should aspire to change – remains unclear.

As the target behavior remains unspecified, prior research has also not met the second requirement for effective intervention design, i.e., to understand the *function* of the target behavior in the context of people's everyday life (Bartholomew et al., 2006; Michie et al., 2014; Robroek et al., 2021). Why do people engage in the target behavior? The fact that these crucial steps in the intervention development process were skipped may explain why many existing interventions, such as changes in the work environment (Hutcheson et al., 2018), the use of activity monitors (Stephenson et al., 2017), or the use of prompting software (Stephenson et al., 2017), have limited effects on people's sitting in the long-term. For research on sitting to move forward and, ultimately, to develop effective interventions, this research area first needs a specification of the target behavior and its function.

In this paper, we take a step back and propose a framework that emphasizes the function of sitting in everyday life. Our framework is designed to aid to the understanding of sitting and standing patterns among people who are ambulatory, i.e., able to stand. First, we propose that the core behaviors of interest are *stand-to-sit* and *sit-to-stand transitions*. Second, we draw on models of goal hierarchies to suggest that people rarely engage in these transitions for the explicit purpose of getting into a sitting or standing posture; rather, these transitions are instrumental in serving more meaningful goals. Third, based on our framework, we provide suggestions for practitioners to design feasible, realistic, and effective sitting behavior interventions. Fourth, we lay out implications for research and theory.

Stand-to-sit and sit-to-stand transitions

Intervention development frameworks emphasize that interventions should be tailored to a specific target behavior (Bartholomew et al., 2006; Michie et al., 2014). However, most prior studies on sitting behavior have failed to specify such a target behavior. In a terminology consensus project, *sedentary behavior* was defined as 'any waking behavior characterized by an energy expenditure of $\leq$1.5 metabolic equivalents (METs), while in a sitting, reclining or lying posture' (Tremblay et al., 2017). This definition refers to a broad category of behaviors ('any waking behavior') rather than a specific target behavior. *Sitting*, in turn, was defined as 'a position in which one's weight is supported by one's buttocks rather than one's feet, and in which one's back is upright' (Tremblay et al., 2017). This definition refers to a physical posture rather than a behavior. These definitions provide useful starting points for sedentary behavior research, but they fail to identify a specific target behavior.

In practice, some researchers use the term *sitting behavior* to refer to a subcategory of sedentary behavior, namely any waking behavior with an energy expenditure $\leq$1.5 MET while in a sitting posture. However, other researchers use the term *sitting behavior* to refer to variation between different sitting postures, such as leaning forward and sitting upright (Huang et al., 2017). This variety demonstrates how the concept of *sitting behavior* may be understood differently by different researchers. Note, however, that both these definitions use *sitting behavior* to refer to a category of behaviors rather than one specific behavior.

Regardless of these definitions, both sedentary behavior and sitting behavior are often operationalized as *sedentary time* or *sitting time*: the total time participants spend sedentary/sitting during a specific time period (e.g., a day). Accordingly, in most interventions, the goal is to reduce sitting time. Yet, *time* is not a behavior. Rather, the time spent engaging in a behavior is an outcome that behavior. For example, a daily sitting time of 6 hours is the outcome of sitting down and standing up numerous times during the day. Some studies focus on the duration of individual periods of uninterrupted sitting – sitting *bouts* – and use *mean bout duration* as an outcome measure. Yet, as with sitting time more broadly, a 'sitting bout' captures the *time spent* in a certain posture, not

behavior itself. In sum, neither the definition of sedentary behavior, the definition of sitting, nor their common operationalizations in terms of sedentary time or sitting bout duration, provide researchers and intervention designers with a precise behavior to target.

We propose that a more helpful approach is to focus on the discrete units of behavior that underlie people's sitting time. Specifically, the time people spend sitting is always an outcome of two discrete behaviors: a stand-to-sit transition (i.e., moving from a standing to a sitting posture) and a sit-to-stand transition (i.e., moving from a sitting to a standing posture). A stand-to-sit transition always starts a period of sitting; a sit-to-stand transition always ends it. Consider a child who enters their classroom at 9 am, and then immediately makes a single stand-to-sit transition – i.e., they sit down at their table. The duration of the sitting bout that follows depends on the timing of the next sit-to-stand transition: if the child takes their next sit-to-stand transition at 11 am, the result will be a 2-hour period of sitting. The stand-to-sit transition and the sit-to-stand transition are the fundamental behavioral units that underpin sitting bouts, and therefore serve as clear target behaviors to explain, predict, or change in research and interventions.

Aside from offering target behaviors, a focus on stand-to-sit and sit-to-stand transitions, rather than sedentary behavior or sitting, has three further benefits:

First, it provides a more ecologically valid picture of people's daily sitting. People make ±70 to ±140 posture transitions a day; also, they may sit or stand for only a few seconds or for several hours (Bohannon, 2015; ten Broeke et al., 2020). As a result, people's sitting behavior strongly varies from day to day and from context to context. This variation is overlooked by the traditional focus on total daily sitting time (Figure 1). Indeed, studies show analyzing people's stand-to-sit and sit-to-stand transitions provides useful insights into how people's sitting behavior varies as a function of time of day (ten Broeke et al., 2020, 2022).

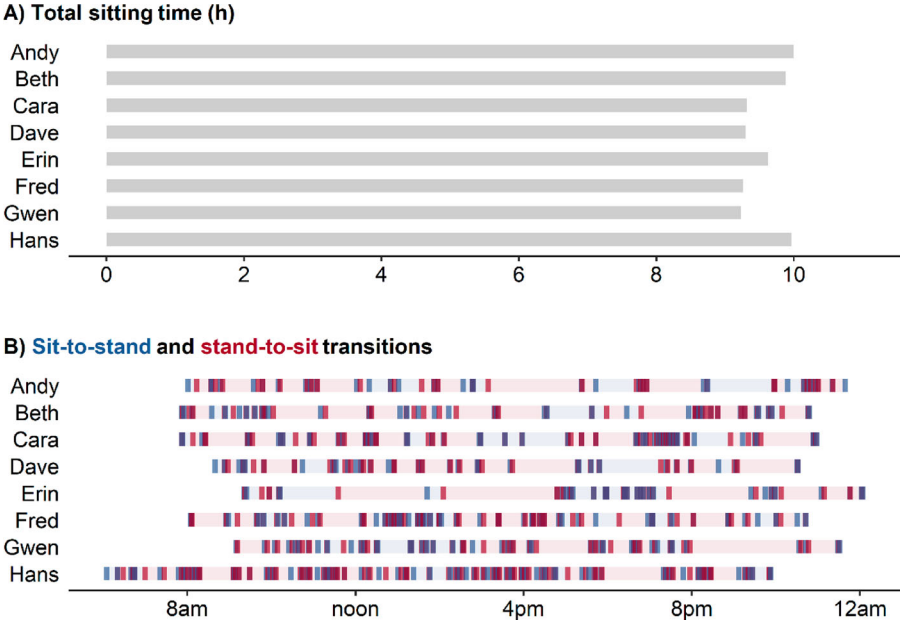

Figure 1. Illustration of two ways to examine sitting behavior. Both panels display the same accelerometry data (i.e., data from eight participants, one single day per participant, from waking up to going to bed; names are pseudonyms; data from; Eversdijk et al., in preparation). (a) Total sitting time in hours, summed over all sitting episodes. (b) Sit-to-stand transitions (blue ticks) and stand-to-sit transitions (red ticks) over the course of the day. Together, these plots illustrate that an analysis of total sitting time overlooks important aspects of sitting behavior (e.g., Erin had several very long stretches of uninterrupted sitting; Hans showed many sit-to-stand and stand-to-sit transitions).

Second, a focus on stand-to-sit and sit-to-stand transitions allows researchers and practitioners to better distinguish between healthy and unhealthy sitting patterns. By itself, sitting is not necessarily unhealthy. Rather, recent studies suggest that health problems develop due to *prolonged*, uninterrupted periods of sitting, i.e., periods of sitting that feature few or no sit-to-stand transitions (e.g., Bailey, 2021). Even though, to date, there is insufficient evidence on how frequently people need to break up their sitting to protect their health, experts generally agree that breaking up prolonged sitting is desirable for health and wellbeing (Biddle & Bennie, 2017).

At the same time, standing – which is often promoted as an alternative to sitting (Bull et al., 2020) – is not always healthy: Engaging in *prolonged* periods of standing – i.e., periods of standing that include few or no stand-to-sit transitions – has negative consequences, such as pain in the lower-limbs and impaired circulation (Messing et al., 2013). As such, sitting patterns that include many long, uninterrupted periods of sitting and/or standing can be considered *unhealthy* sitting patterns, whereas sitting patterns that include frequent sit-to-stand and stand-to-sit transitions can be considered *healthy* sitting patterns (Healy et al., 2008; Júdice et al., 2016; Swartz et al., 2011). Focusing on bout duration rather than total daily sitting time already allows researchers to distinguish between healthy and unhealthy sitting patterns. A focus on stand-to-sit and sit-to-stand transitions would allow for researchers to shift attention from the bout itself to the actual behaviors at the start and end of the bout, thereby providing targets for interventions to promote healthy patterns of sitting.

Third, 'break up sitting more often' might be a clearer and more feasible public health message than 'sit less', which people often misinterpret as an endorsement of prolonged standing. Encouraging people to reduce sitting time, yet avoid standing for prolonged periods, has been shown to cause confusion among the general public (Gardner et al., 2017).

In sum, both sitting behavior research and interventions should move away from its current focus on understanding sitting time, and instead focus on understanding and/or changing stand-to-sit and sit-to-stand transitions. Specifically, interventions could focus on increasing the frequency of sit-to-stand transitions.

A goal-based perspective

Once a target behavior has been identified, the next requirement for effective intervention design is to understand the *function* of that behavior in people's daily lives (Bartholomew et al., 2006; Michie et al., 2014; Robroek et al., 2021). A qualitative exploration of the role of sitting in older adults' daily life showed that sitting was strongly embedded in older adults' everyday activities (Palmer et al., 2019), such as socializing, relaxing, or reading. In other words, sitting seems instrumental to meet the goals of everyday life. Building on this, we draw on models of goal hierarchies to further specify the function of stand-to-sit and sit-to-stand transitions in the context of daily life.

Goal hierarchies

To understand why people do or do not perform stand-to-sit and sit-to-stand transitions, we need to consider the goals that people attempt to achieve by such transitions (Austin & Vancouver, 1996; Vallacher & Wegner, 1987). *Goals* are mental representations of desired outcomes (Fishbach & Ferguson, 2007). Goals energize and direct behavior through the following mental process: First, an evaluation of the difference between a current state (e.g., 'an unread report') and the goal state (e.g., 'having read the report') takes place; next, based on the result of this evaluation, behaviors that could reduce the discrepancy between the goal state and the current state are initiated (e.g., 'read the report'; Fishbach & Ferguson, 2007).

A common principle in most goal theories (Austin & Vancouver, 1996; Vallacher & Wegner, 1987) is that goals and behavior are structured in a hierarchy (Figure 2), with broad goals at higher levels (e.g., 'perform well at work'). These broad, higher-order goals are served by lower-order goals or

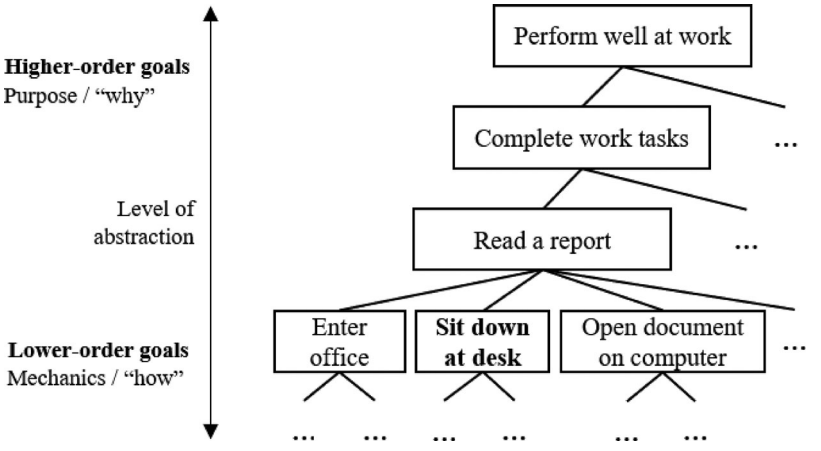

Figure 2. Schematic visualization of a goal hierarchy for the higher goal to perform well at work. The figure illustrates how stand-to-sit transitions are often relatively lower-order behaviors.

behaviors (e.g., 'complete work tasks'), which are, in turn, served by lower-order goals or behaviors (e.g., 'read a report'), which are served by yet lower-order goals or behaviors (e.g., 'enter office', 'sit down at desk', 'open document on computer', etc.). Higher-order goals often reflect the purpose and consequences of the behavior (*why* people do something). Lower-order goals often reflect the behavioral mechanics that are involved in the behavior (*how* people do something; Vallacher & Wegner, 1987).

Generally, people have multiple higher-order goals, which can be congruent (such that pursuing one goal does *not* divert time, energy, or attention from pursuing another goal) or incongruent (such that pursuing one goal necessarily diverts time, energy, or attention from pursuing another goal; Fishbach & Ferguson, 2007). For instance, a student who cycles to school can simultaneously attain the goal to commute to school *and* the goal to be physically active. However, a student who can only commute to school by car cannot concurrently achieve these two goals. When goals compete, people have to decide how to invest their time, energy, and attention at that moment, by prioritizing one goal over another (Fishbach & Ferguson, 2007).

Once a high-priority higher-order goal is selected, this goal activates a sequence of lower-order behaviors that serve attainment of that goal (Austin & Vancouver, 1996). For instance, the goal to 'read a report' may activate the sequence 'enter office', 'sit down at desk', and 'open document on computer'. As people repeatedly perform a sequence of actions, the execution of the sequence can become habitual. A *habit* refers to the process by which the tendency to perform a certain behavior is directly triggered upon encountering a certain context cue, without the need for conscious deliberation or planning regarding whether and how to perform the behavior (Gardner, 2015). Habits are formed over time, when people repeatedly engage in the same behavior in response to a given context cue (Wood & Rünger, 2016). In a sequence of lower-order behaviors that together serve a higher-order goal, completion of one behavior in the sequence serves as the cue that habitually triggers the next behavior (for a discussion of this idea, see Gardner, Phillips, et al., 2016). Thus, completing the act of 'enter office' habitually triggers 'sit down at desk', completing 'sit down at desk' habitually triggers 'open document', and so on. This chain of habits enables people to perform the sequence of behavior to 'read a report' quickly and efficiently, without the need to consciously attend to each step (Austin & Vancouver, 1996).

Besides providing a perspective on how people's behavior is driven by goals, hierarchical models of goals also help understand how people think about, and reflect on, their own behavior. Specifically, Action Identification Theory (Vallacher & Wegner, 1987) posits that people are naturally inclined to reflect on the broader meaning and consequences of their actions, rather than on mechanistic

details. This is because information about meaning and consequences of behavior helps people to plan ahead and to monitor their progress towards long-term ambitions. To illustrate, thinking about an act as 'I am reading a report' provides more meaningful information about life than thinking about the same act as 'I am sitting at my desk and reading text'. Action Identification Theory posits that people, when possible, people tend to consciously reflect on their behavior in terms of higher-order goals rather than lower-order behaviors.

Stand-to-sit and sit-to-stand transitions are means to higher-order goals

The perspective laid out above raises the question of where stand-to-sit and sit-to-stand transitions fit in the hierarchy of goals. To some extent a goal or behavior's place in a hierarchy is relative. For example, 'read a report' is a lower-order goal than 'complete work tasks', yet a higher-order goal than 'sit down at desk' (Figure 2). Nonetheless, we argue that stand-to-sit and sit-to-stand transitions are almost invariably lower-order behaviors that serve the pursuit of higher-order, more meaningful goals.

To illustrate: People make stand-to-sit transitions to complete work tasks, to play videogames, to watch television, to eat dinner, to read a book, and so on. People make sit-to-stand transitions to fetch a drink from the kitchen, to close a window, to go to the bathroom, to ask a colleague a question, to get off the bus, and so on. On occasion, people may purposefully stand to 'stretch their legs' (e.g., after a long drive), or they may purposefully sit to recover (e.g., after a long stretch of standing). For the most part, however, people rarely make stand-to-sit or sit-to-stand transitions for the sake of being in a seated or standing posture per se. Rather, stand-to-sit and sit-to-stand transitions are usually means towards more personally meaningful goals. And, as people are naturally inclined to consciously reflect on higher-order goals, not lower-order behaviors (Vallacher & Wegner, 1987), we suggest that people will usually pay little attention to their stand-to-sit and sit-to-stand transitions.

Research on how sitting activities are mentally represented indeed suggests that people rarely reflect on their own behavior in terms of their posture. For example, in one study, participants were asked to describe three recent 'experiences that they had done or that had happened to them' in the last three months (Gardner et al., 2019). Participants almost exclusively described these actions in terms of some higher-order goal or outcome (e.g., 'I was driving my car'); participants rarely referred to their posture (e.g., 'I was sitting'). In another study (Gardner et al., 2019), participants were provided with 10 action labels (e.g., 'getting my work done', 'processing information', 'looking at a monitor', 'sitting') and were asked to rank these labels according to 'how well they describe what you personally do at your desk'. By and large, participants rated labels based on higher-order goals (e.g., 'getting my work done') to be more descriptive than labels based on posture (e.g., 'sitting').

The idea that stand-to-sit and sit-to-stand transitions are lower-order behaviors is further supported by behavioral data. In the Active Buildings Study (Smith et al., 2015; Spinney et al., 2015), office workers wore an activity monitor for several days. On workdays, workers showed most standing and moving behavior between 7–9 am, 12–2 pm, and 5–7 pm (Smith et al., 2015). This finding suggests that sit-to-stand transitions (and the standing episodes that ensued) were triggered by the higher-order goals to commute to work, to fetch lunch, and to commute home. During working hours, workers generally sat for long, uninterrupted periods of time at their desk location; they only interrupted their sitting to visit other office locations, such as the copy room or kitchen (Spinney et al., 2015). In sum, participants only made sit-to-stand transitions when their work tasks, or their need for refreshments, compelled them to visit other locations.

In sum, we assume that the function of stand-to-sit and sit-to-stand transitions in people's daily lives is to serve higher-order goals; stand-to-sit and sit-to-stand transitions rarely function as personally meaningful goals themselves. Although intuitive, this assumption is often overlooked and it has implications for interventions, theory, and research.

Implications for interventions

Our framework offers two general pieces of advice for intervention designers. First, interventions should aim not to limit sitting time, but rather, to increase the frequency of sit-to-stand (and stand-to-sit) transitions. Second, to achieve this aim, intervention designers should consider the higher-order goals that are served by these transitions. Specifically, whereas prior interventions attempted to change the prioritization of higher-order goals, we suggest that a more promising strategy is to capitalize on the higher-order goals that people already pursue.

Changing goal prioritizations: an uphill battle?

Adults generally value health-related goals such as 'improve one's health' and 'prevent disease' (Lau et al., 1986). To achieve such goals, they are generally willing to change their sitting behavior (Hadgraft et al., 2018). Accordingly, it seems viable to encourage people to prioritize health goals over goals that trigger sitting for prolonged periods of time. Problematically, however, modern society strongly affords sitting in virtually all contexts (Rietveld, 2016) and most high-priority daily-life goals (e.g., 'perform well at work', 'participate in classes', 'socialize') are easiest to attain while sitting. So, goals that trigger frequent posture transitions (e.g., 'improve one's health') are often incongruent with other high-priority goals (e.g., 'perform well at work'). Indeed, office workers often emphasize that they refrain from taking frequent standing breaks because these disrupt concentration or otherwise interfere with productivity (e.g., Gilson et al., 2011; O'Dolan et al., 2018). Therefore, we posit that trying to change people's goal priorities will often be an uphill battle. Previous interventions have nonetheless attempted to change sitting behavior using such goal-incongruent approaches, with varying degrees of success.

Many sitting behavior interventions have included components that aim to increase knowledge about sedentary behavior, or develop self-regulatory skills, such as goal setting and self-monitoring (Gardner, Smith, et al., 2016). For instance, some interventions include workshops in which participants learn about the negative health consequences of sedentary behavior (Biddle et al., 2015). Other interventions include motivational consultations, in which participants formulate, and then reflect on, goals to sit less (Opdenacker & Boen, 2008). Despite that participants may well be motivated to attain their new goals (e.g., 'sit less'), we suspect that, for many, these goals will be incongruent with other high-priority goals that are served by prolonged sitting. Indeed, interventions relying on health education and behavioral strategies typically yield weak effects (Chu et al., 2016).

Sitting behavior interventions also frequently include time-based sit–stand schedules – i.e., fixed instructions regarding when to perform sit-to-stand (and/or stand-to-sit) transitions. For instance, sit–stand schedules are often administered to people who have access to height-adjustable desks. In one study, participants were provided with height-adjustable desks and instructed to stand for 10 minutes every hour (Barbieri et al., 2017). In another study, participants were instructed to switch between sitting and standing at least every 30 minutes (Neuhaus et al., 2014). It is unrealistic to expect that fixed, time-based schedules will align with people's ongoing, high-priority goals. For example, fixed schedules may require people to make sit-to-stand transitions (or transition their desk to standing height) in the middle of work meetings or while working on tasks that require concentration. The effectiveness of sit–stand schedules thus relies on people's willingness to prioritize the scheduled sit-to-stand transitions over these work-related goals. As a result, people find it difficult to adhere to such fixed schedules in the long term. Scheduling problems may explain why desk-based workers with height-adjustable workstations often fail to structurally use the standing option as intended (Hutcheson et al., 2018; Renaud, Huysmans, et al., 2020).

Many behavior interventions include time-based prompts, which are close cousins of sit–stand schedules. Time-based prompts are typically delivered via signals on a computer, mobile phone, or smartwatch, which remind individuals to stand up after sitting for a pre-determined time-period, often 30 minutes (Evans et al., 2012). People may receive prompts while eating dinner,

while attending a lecture, or while playing a videogame. So, like time-based sit–stand schedules, time-based prompts rely on people's willingness to prioritize the prompted sit-to-stand transition over other higher-priority goals. As a result, time-based prompts often trigger frustration due to their disruptive nature (Cooley et al., 2014). As with sit–stand schedules, people tend to disengage from time-based prompts over time (Stephenson et al., 2017).

Capitalizing on existing high-priority goals: a promising strategy?

A promising alternative to trying to change people's goal prioritizations is to capitalize on the goals that people already prioritize. That is, we propose that interventions should aim to create circumstances in which pre-existing high-priority goals trigger people to frequently make sit-to-stand and stand-to-sit transitions – or if that is not feasible, to at least create circumstances in which sit-to-stand and stand-to-sit transitions do not hinder the pursuit of existing high-priority goals. We describe four strategies to increase sit-to-stand transitions in congruence with people's everyday goals.

Changing affordances

An *affordance* is an aspect of the social and/or physical environment that invites an individual to engage in certain behavior (e.g., a chair affords sitting; Rietveld, 2016). To encourage frequent sit-to-stand transitions, interventions could focus on restructuring the environment to create affordances that invite people to engage in frequent sit-to-stand transitions while pursuing ongoing high-priority goals. For example, height-adjustable desks, if accompanied with proper user-instructions (see also 'Planning at task-boundaries' and 'habit formation') are a promising tool, as they enable people to perform their work while standing (e.g., Minges et al., 2016; Shrestha et al., 2018). Wireless laptops and portable video displays afford mobile learning and working (Lanningham-Foster et al., 2008). In addition, workplace or classroom designers could place often-needed objects (e.g., a waste bin) outside arm's reach (Löffler et al., 2015). At work, creating affordances to increase sit-to-stand transitions could also mean moving facilities (e.g., printers, coffee machines) closer, as large distances to shared facilities may lead people to collect multiple tasks and carry them out at once using minimal sit-to-stand transitions (Fisher et al., 2018; Löffler et al., 2015).

Planning at task-boundaries

To prevent interference with ongoing high-priority goals, interventions could encourage sit-to-stand (and stand-to-sit) transitions specifically at *task boundaries*, i.e., the moments between the completion of one task and the start of a new one (Dewitt et al., 2019). Examples of task boundaries are after ending a phone call, or when a commercial break starts during a TV show. At task boundaries, posture transitions are less likely to disrupt the pursuit of some high-priority goal. Also, people are more likely to remember to act (e.g., to make a sit-to-stand transition) at task boundaries, compared to during ongoing tasks (e.g., Zacks & Swallow, 2007). Moreover, it is important to realize that many people prefer sitting over standing while performing certain tasks, such as participating in meetings (during which standing may be socially unacceptable; Mansfield et al., 2018) and doing focused work (Renaud, Spekle, et al., 2020). As such, task boundaries may be optimal moments to engage in sit-to-stand transitions.

Rather than fixed, time-based prompting techniques, intervention designs that use machine learning algorithms to determine optimal moments for intervention (e.g., just-in-time adaptive interventions; Nahum-Shani et al., 2018), could be promising tools to prompt sit-to-stand transitions at task boundaries. Moreover, planning at task-boundaries could improve the effectiveness of existing interventions. That is, rather than using fixed, time-based sit-stand schedules or prompting techniques, planning at task boundaries will likely improve the use of height-adjustable desks (Renaud, Spekle, et al., 2020). For example, users may be instructed to plan desk transitions

between sitting height and standing height at specific, personally-preferred task-boundaries during the day (e.g., when starting a phone call).

Habit formation

When sit-to-stand transitions at task boundaries do not spontaneously occur and cannot be prompted, people can be trained to form habits that connect the completion of a specific task to a sit-to-stand transition. For example, one could link the act of standing up to environmental cues such as pressing the 'send' button on an email, hanging up the phone, or seeing the start of a TV commercial break. How to use habit formation for behavior change is described in detail elsewhere (Gardner et al., 2020). Previous intervention studies (e.g., on balance and strength training in older adults; Clemson et al., 2012), have effectively applied habit-formation to embed health behaviors into people's everyday activities.

Intervention reframing

We suggest it may help to reframe interventions to be more in line with the higher-order goals that people already pursue. Specifically, the goal to work productively (at the office) often prevents sit-to-stand transitions. Yet, research clearly shows that frequent standing breaks boost, rather than harm, productivity (Chrismas et al., 2019; Giurgiu et al., 2021; Kar & Hedge, 2020; Renaud, Spekle, et al., 2020). Thus, productivity interventions that capitalize on the known positive effect of taking (standing) breaks (e.g., based on the pomodoro technique; Cirillo, 2018), could be promising. Speculatively, productivity interventions could function as a double-edged sword: They may increase productivity, by making use of sit-to-stand transitions that support – rather than thwart – the goal to perform well at work.

Taken together, our framework calls for intervention designers to adapt their designs to people's pre-existing routines and schedules as much as possible. By acknowledging and capitalizing on people's pre-existing high-priority goals, intervention designers may be able to ensure a more fluent and less frustrating experience for participants, which should improve adherence and effectiveness on the longer term.

Implications for theory

Self-reported cognitions about sitting

Studies on the psychological determinants of sitting have often focused on cognitive constructs, such as people's *intentions* related to sitting (e.g., 'I intend to sit less'; Prapavessis et al., 2015) or their *intrinsic motivation* to sit (e.g., 'It's fun to sit'; Gaston et al., 2016). Yet, as outlined above, people typically do not reflect on their sitting behavior; instead, people reflect on their behavior in terms of higher-order goals. This idea has implications for the use of self-report in sitting research, as it may not be easy for people to self-report on their own sitting behavior or related cognitions.

Prior research indeed shows that people have difficulties answering questions about their own sitting behavior. For example, one study showed that, when asked to self-report their sitting time in a questionnaire, people estimated their sitting time by calculating post-hoc how much time they spent in pursuit of various higher-order goals that are served by sitting (e.g., watching television, desk-based work, eating dinner; Gardner et al., 2020). A meta-analysis demonstrated that in self-report, people underestimate their sitting time by more than 1.5 hours compared to device-based measurement (Prince et al., 2020).

Similar difficulties arise when people self-report on their attitudes or intentions towards sitting. When confronted with a question such as 'How much time do you plan to spend sitting on weekdays in the upcoming week?' (Prapavessis et al., 2015), we suggest that people will usually have no pre-existing intention. As such, they likely *create* an intention on the spot (Ogden, 2003). For example, to come up with an answer, people may infer their intentions from their actual sitting (i.e., 'I sit all day,

so I probably have weak intentions to limit my sitting time') or answer based on what they think is socially desirable (Ogden, 2003). As a result, responses to self-report questions will typically be invalid reflections of people's intentions, attitudes, or motivations regarding sitting.

We thus suggest that the intentions, attitudes, or motivations that people report in response to questionnaires will be unhelpful to explain, predict, or change sitting in its natural context. This idea is consistent with studies on older adults' sitting behavior (Maher & Dunton, 2019, 2020). Participants wore an activity monitor for a week and filled out a questionnaire on their mobile phone six times a day, which contained items about their intentions to limit their sitting time in the next two hours. Results showed that when participants reported strong intentions to sit less in the next two hours, they did show less sitting time in that two-hour window. Importantly, however, this effect depended on the time of day: during evenings, there was no evidence for a link between intentions to sit less and actual sitting. These results suggest that, although people can be pushed to form intentions to limit their sitting time, such intentions may readily be overruled. Plausibly, this happens when people prioritize a higher-order goal that biases them towards sitting (e.g., 'have dinner', 'watch TV').

In sum, although previous studies on the cognitive determinants of sitting have been valuable in initiating discussions on the psychology of sitting, our framework suggests that the assessment of explicit cognitions regarding sitting may be misplaced.

Goal-directed and habitual sitting

Our framework, which suggests a key role for goals, may appear at odds with claims that sitting is *habitual* (Maher et al., 2021). Habitual behavior is often portrayed as goal-independent, as this behavior is typically triggered by a contextual cue, potentially in the absence of intentions (Gardner, 2015; Wood & Rünger, 2016). On the contrary, however, our framework reconciles goal-based and habit-based perspectives on sitting. Stand-to-sit and sit-to-stand transitions may often be habitual, as they may be directly triggered by the completion of prior actions in a sequence (e.g., entering one's office). At the same time, these habitually triggered stand-to-sit and sit-to-stand transitions are goal-directed, as the behavioral sequences which they are part of ultimately serve higher-order goals (e.g., 'complete work tasks'). That is, because habitual behavior is quick and efficient, the habitual nature of entering one's office and sitting down at one's desk will benefit the accomplishment of completing one's work tasks. So, contrary to suggestions that action must be *either* goal-directed *or* habitual (Conroy et al., 2013; Maher & Dunton, 2019; Stults-Kolehmainen et al., 2020), our framework suggests that goals and habits play interrelated, complementary roles in producing sitting behavior.

Conclusion

In recent years, the science of sitting has begun to consider the unique health consequences and the potentially unique determinants of sitting: The World Health Organization has included sedentary behavior in their physical activity recommendations (Bull et al., 2020); the Sedentary Behavior Research Network developed a consensus definition of sedentary behavior as distinct from physical inactivity (Tremblay et al., 2017); and several researchers cataloged the fundamental differences between sitting behavior and other health behaviors (Biddle, 2011; van der Ploeg & Hillsdon, 2017). In this paper, we took two further steps that are necessary for designing effective sitting behavior interventions: we established the target behavior of interest and we specified and acknowledged the function of this target behavior in people's daily lives. We encourage intervention designers to use this framework to guide the development of sedentary behavior interventions, and we encourage researchers to consider our framework in designing future research on predicting and explaining sitting behavior. In this way, our framework works towards interventions that are practical, feasible, and acceptable, and so more likely to encourage long-term behavioral change.

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