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Work pattern causes bias in self-reported activity duration: a randomised study of mechanisms and implications for exposure assessment and epidemiology

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Abstract

Background—Self-reported activity duration is used to estimate cumulative exposures in epidemiological research.

Objective—The effects of work pattern, self-reported task dullness (a measure of cognitive task demand), and heart rate ratio and perceived physical exertion (measures of physical task demands) on error in task duration estimation were investigated.

Methods—24 participants (23–54 years old, 12 males) were randomly assigned to execute three tasks in either a continuous (three periods of 40 continuous minutes, one for each task) or a discontinuous work pattern (40 min tasks each divided into four periods of 4, 8, 12 and 16 min). Heart rate was measured during tasks. After completing the 2 h work session, subjects reported the perceived duration, dullness and physical exertion for each of the three tasks. Multivariate models were fitted to analyse errors and their absolute value to assess the accuracy in task duration estimation and the mediating role of task demands on the observed results.

Results—Participants overestimated the time spent shelving boxes (up to 38%) and filing journals (up to 9%), and underestimated the time typing articles (up to −22%). Over- and underestimates and absolute errors were greater in the discontinuous work pattern group. Only the self-reported task dullness mediated the differences in task duration estimation accuracy between work patterns.

Conclusions—Task-related factors can affect self-reported activity duration. Exposure assessment strategies requiring workers to allocate work time to different tasks could result in biased measures of association depending on the demands of the tasks during which the exposure of interest occurs.

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Cumulative time-weighted measures of exposure to physical and chemical agents are frequently used in occupational and environmental epidemiological research.[1, 2] The validity of these cumulative measures relies on the accuracy with which time spent at multiple locations or executing different jobs, tasks or activities with expected different levels of exposure can be estimated. This exposure information about time spent at different places or carrying out different activities is often based on self-reported information and constitutes an essential input for estimating cumulative exposures to a variety of health hazards including, for example, air pollutants,[3, 4] pesticides,[5, 6] electromagnetic fields,[7] ionising radiation[8, 9] and ergonomic demands.[10, 11] Although reliance on self-reported exposure durations remains of great concern to epidemiologists due to the bias that can be introduced in estimating dose–response relationships, their use has been largely unavoidable[12] as more objective exposure assessment methods are too costly,[3, 13] cannot be employed in retrospective epidemiological studies,[14, 15] are of limited use when privacy has to be maintained,[16, 17] and are presumably even less accessible in unprivileged regions. Therefore, a comprehensive assessment of the properties of such self-reported information is warranted to better understand the effect the use of these data has on cumulative exposure and dose–response estimates in epidemiological research.[18, 19]

Few studies have systematically investigated the determinants of response accuracy and individuals' capacity to recall the time spent at different work activities.[20] Cognitive scientists have studied how the characteristics of short duration events can potentially affect the perception of their duration.[21] However, whether these findings can be generalised to occupational and daily life settings is uncertain. Pilot and validity studies conducted within the context of epidemiological research have allowed candidate factors influencing the individual's perceived duration of their exposures to be identified.[22, 23] This information has also been useful for exploring the presence of exposure misclassification and indicating the expected direction of the bias to the estimated measures of association. However, this study-specific information does not allow the source and mechanisms behind exposure misclassification to be identified with certainty, which can limit the interpretation of measures of association and the extent to which they represent causal effects.

This study investigated task-related determinants and mechanisms behind the accuracy of self-reported event durations for occupational epidemiological research using an experimental approach so that other determinants of individuals' capacity to report exposures could be isolated. More specifically, this study assessed whether the accuracy of self-reported durations of tasks is influenced by the cognitive and physical demands of the tasks and the work pattern (ie, continuous versus discontinuous) in which tasks are executed. Assessing the effect of work pattern on the perceived duration of the tasks is particularly important because modern work organisation has resulted in jobs that require the worker to alternate frequently between multiple tasks at different times.[24] Also, because the work pattern can change tasks demands,[25, 26] and because task demands may change their perceived duration,[27] this study explores whether potential differences in the accuracy of self-reported task durations are mediated through changes to the physical and cognitive demands of the tasks when executed continuously or discontinuously. Specifically, we hypothesised that the duration of tasks will be overestimated or underestimated differently depending on the task and that the degree of overestimation or underestimation will vary depending on the work pattern. This informs potential sources of bias to self-report based cumulative measures of exposure, allows better understanding of the use of self-reported activity duration in the dose–response estimates, and suggests improved ways of using self-reported information in exposure assessment.

METHODS

Participants

Twenty four participants (12 men and 12 women) were recruited through newspaper advertisements and flyers posted at a university between October and December 2006 in Boston, Massachusetts, USA. Eligibility criteria were: (1) age between 18 and 60 years; (2) having a current job or having been searching for a job during the past year; and (3) having had no musculoskeletal pain or discomfort in the previous month that prevented work or personal activities or required medical treatment. The Human Subjects Committee of the Harvard School of Public Health approved all experimental procedures.

Experimental design and procedures

Eligibility verification and participant enrolment were conducted by Dr Lope Barrero. Eligibility was verified through a standardised 2 min telephone interview with potential participants. A roster of eligible candidates was created from which a random sample of 24 participants was selected and contacted to schedule an appointment for the experimental session. There was little prior research to guide sample size calculations. Using standard methods for comparison of means, we determined that a sample size of 20 participants in each group would be needed to detect a difference of 0.88 standard deviations between groups with type I error of 0.05 (two-sided) and power of 0.80. Practical constraints on resources and study times ultimately led us to choose a sample size of 12 participants in each group. With 24 participants, the study had power of 0.80 for a difference between groups of 1.15 standard deviations and power of 0.60 for a difference of 0.91 standard deviations.

Participants were assigned at random to continuous versus discontinuous work patterns subject to the restriction that 12 participants would be assigned to each work pattern. Within work patterns, participants were randomised to sequences at random subject to constraints defined by the requirement for balance and the constraint in the discontinuous group that work type must change between successive periods. All random allocations described were conducted using computer generated random lists. Participants in the two work pattern groups were similar with regard to age, height, mass, body mass index (BMI), years of education and amount of work executed (table 1). Participants in both groups spent 40 min in each of three tasks (shelving boxes, typing articles and filing journals), for a total work session of 2 h. The continuous group completed the three tasks in three consecutive 40 min periods, one for each task. The discontinuous group completed each of the three tasks four times, each time having different segments of 4, 8, 12 and 16 min totalling 40 min per task. Participants were asked to change between tasks by a recording preprogrammed in a computer. The average order in which tasks were performed in the two experimental groups (for the discontinuous work pattern, the average order in which each task was conducted by each participant was first estimated so that this comparison could be conducted) was not significantly different (Kruskal-Wallis test, $p = 0.450$).

The three repetitive tasks were shelving boxes, typing articles and filing journals. These tasks were designed to have distinctly different levels of physical and cognitive demands to minimise any error in duration perception due to lack of distinctiveness between the tasks.[27] The duration of 40 min for each task was chosen to minimise the effect that the true duration of tasks has on the accuracy of the responses; it has been reported that tasks with short durations (ie, 2.5 min) are overestimated, while tasks with long durations (ie, 37.5 min) can be more accurately estimated.[20] For shelving boxes, participants were asked to pick up document boxes (approximately 1.6 kg) with a four-letter label from the floor, check them off from an alphabetical list and place them on a shelf. For typing articles, participants were asked to type the title, last name of the first author and page number from the first page of a variety of scientific journal articles. For filing journals, participants were asked to pick up one scientific journal at a time out of several stacks located on a table and file them into bins located 20 cm above the participant's shoulder level and at 112 cm above the floor.

Participants were asked to perform the tasks accurately and at a comfortable rate. Each individual was unaware of the existence of other work patterns in which they could potentially have executed the assigned work. While participants were told during the informed consent procedure that they would complete a questionnaire after finishing the tasks, they were not informed about the specific questions nor about the specific purpose of the study beyond the fact that it was a general exposure assessment study. These instructions were meant to emulate occupational epidemiological research where workers are frequently asked to report their exposures without previous notice concerning the work aspects about which information is needed. Participants were not allowed to wear a watch and all displays of time within the immediate laboratory area including that on the user's computer were removed.

All sessions were video-recorded (JVC Everio, Yokohama, Japan). Also, heart rate was monitored in real time during the tasks so that the effect of the physical demands of the tasks on the perception of their duration could be investigated using a comparable metric. Heart rate was sampled every 5 s and values averaged per minute during the 120 min of the work sessions (Polar S810, Polar Electro, New Hyde Park, New York, USA).

Outcome

Two measures of accuracy of reported task durations were analysed: signed errors and absolute errors. The signed errors were calculated as the difference between the participant's estimated duration of each task and the actual duration of the task (40 min). Signed errors could be greater than 0 (overestimation) or less than 0 (underestimation). Absolute errors were calculated as the absolute value of the signed errors. The average of the signed errors was interpreted as the average direction (underestimation or overestimation) in the error of the task duration estimations. The average of the absolute errors is a measure of the accuracy of task duration estimates.[28]

Within 10 min of completing the entire work session, participants in both groups were asked to respond to a self-administered questionnaire. They were informed in writing in the instructions section of the questionnaire that the total amount of work was 2 h, which was intended to mimic real work situations where workers know the duration of their work shift.

Three identical questions regarding the perceived duration of each task were asked of all participants (eg, "During the past set of tasks, for how long were you shelving boxes/typing articles/filing journals?" using an open ended response (ie, ___hours ___minutes). A duration scale was preferred as opposed to proportions because it has been suggested that workers may find it more difficult to estimate the latter.[29] The three questions were presented to participants on a single page with duration of shelving boxes listed first, duration of typing articles listed second and duration of filing articles listed third. No instructions were provided on the order in which the questions should be answered or how participants should estimate task durations. This was thought to favour time allocation based on the perception of the task's duration relative to the 2 h period.

Independent variables

The primary independent variables were experimental group (ie, whether the work pattern was continuous or discontinuous) and task (shelving boxes, typing articles and filing journals). The physical demand of the tasks (heart rate ratio), the cognitive demand of the tasks (ie, self-reported level of dullness of the tasks) and the perceived physical exertion of the tasks were also considered as potential determinants of the estimation of task durations. The heart rate ratio was calculated as the average heart rate for the task divided by the resting heart rate.[19] The resting heart rate was the average heart rate registered during the second minute of a 2 min period when the participant was seated comfortably with their arms resting on the forearm supports of a chair and their heads leaning back against the wall. For the self-reported level of task dullness, we asked participants to report their level of agreement/disagreement with the following statement (adapted from one of the questions used to assess subjective job quality perception in the first European Survey of Life Quality[30]): “The task shelving boxes/typing articles/filing journals was dull or boring”. The question used a 5-category Likert-response scale: “Strongly disagree”, “disagree”, “neither agree nor disagree”, “agree” and “strongly agree”. For the perceived physical exertion, we asked participants to report their perceived physical exertion in each task using a 14-category Borg scale.[31]

Data analysis

The signed errors were analysed jointly using an analysis of response profiles[32] with an unstructured covariance matrix (PROC MIXED, SAS v 9.1) with the following independent terms: experimental group (continuous versus discontinuous work pattern), task (shelving boxes, typing articles, filing journals) and their interaction. The same procedure was used with the absolute errors. In these analyses, the primary research question was related to the significance of the term for interaction between work pattern and task. That is, we sought to test whether participants tend to overestimate some tasks at the expense of the underestimation of other tasks, and whether this pattern differed between the continuous and discontinuous work patterns.

To test possible pathways through which potential differences in the errors in task duration estimations by work pattern and task might be caused, a mediated-moderation analysis was conducted.[33] This type of analysis (mediating analysis) allows for testing of potential mechanisms behind observed changes in the outcome of interest in randomised trials.[34] In the present study, it was used to test whether the work pattern changed the estimated task duration errors indirectly via changes in the physical demands (as measured by the heart rate ratio of the tasks), cognitive demands (as measured by self-reported task dullness) or perceived physical demands (as measured by a 14-category Borg scale) of the tasks (fig 1). In brief, the mediated-moderation analyses specify both the regression models that should be built and the regression parameters that are of interest in these models (fig 1). The specified regression parameters of interest were tested with standard tests of fixed effects of regression coefficients in multivariate regression models (multivariate Wald tests). Two separate regression models for each hypothesised mediating variable were constructed to test: (1) the effect of the work pattern, the task and the interaction between work pattern and task on the hypothesised mediating variables (model 1, fig 1); and (2) whether there is an effect of these mediating variables on the error in the estimation of the task durations beyond the effect of the work pattern, the task and their interaction (model 2, fig 1). When there are significant effects of the task by group interaction on the mediator variable, and of the mediator variable on the outcome (error), then the point estimate and the standard error of the mediated moderation effect are estimated.[35, 36]

RESULTS

The times taken shelving boxes and filing journals were on average overestimated (8.3 min (20.6%) and 2.4 min (5.9%), respectively), while the time taken typing articles was underestimated (6.9 min (−17.2%)). Participants working in a discontinuous work pattern overestimated the time taken when shelving boxes (15 min (37.7%)) and filing journals (3.7

min (9.2%)) and underestimated the typing task time (8.8 min (−21.9%)) compared to participants in the continuous work pattern (signed error, fig 2) ($p< 0.001$). The absolute errors, which measure the overall accuracy of the duration estimations, were greater among participants in the discontinuous work pattern than among participants in the continuous work pattern, except for the filing task for which the absolute error was similar between work patterns (absolute error, fig 2) ($p = 0.130$). Although both signed errors and absolute errors consistently indicated that greater inaccuracy existed when reporting the duration of the shelving and typing tasks, the differences between work patterns were smaller for the absolute errors.

The observed differences by work pattern and task in the duration estimation errors were mediated through the reported dullness of the tasks. Participants in the discontinuous work pattern tended to report a higher level of dullness for the filing and shelving tasks but a lower level of dullness for the typing task compared to participants in the continuous group (table 2, dependent variable: dullness); and the perceived dullness of the tasks was positively related to the errors in the estimated duration of the tasks after adjusting for work pattern and task (table 3, dependent variable: signed error).

Although there were strong differences in the physical demands of the tasks (as measured by both heart rate ratio and perceived physical exertion), those differences were not dependent on the work pattern in which those tasks were executed (table 2, dependent variable: heart rate ratio and perceived physical exertion, respectively). Therefore, these variables were not considered as mediators of the observed differences in errors in task duration estimation across work patterns and tasks.

DISCUSSION

The accuracy of self-report based cumulative exposures and measures of association depends on an improved understanding of the determinants of activity duration perception. This is especially important as occupational and environmental epidemiological research frequently, and many times unavoidably, uses self-reported information on activity duration as an input to quantify cumulative exposures.[3–5, 7, 10, 37] This study investigated whether the accuracy of self-reported durations of tasks is influenced by the work pattern in which tasks are executed and whether potential differences by work pattern were mediated through the perceived dullness, heart rate ratio and the perceived physical exertion of tasks. We found that the duration of the tasks that make up a job can be overestimated at the expense of underestimating other tasks and that this phenomenon can be significantly modified by whether the person works continuously for longer periods of time or discontinuously for shorter periods of time alternating between tasks. In this study, the overall degree of overestimation or underestimation of the duration of the tasks somewhat paralleled the heart rate ratio of the tasks. We also found that the work content, specifically the perceived dullness of the tasks, is likely to have mediated the differences in the accuracy of estimated duration by work pattern and task.

Error in estimation of task durations can be mainly ascribed to perception and/or the cognitive estimation procedure.[38] In this study the size of the errors was dependent on the task, with shelving boxes resulting in the higher signed and absolute errors. This result indicates that the differences in content of the studied tasks are an important determinant of their perceived duration. More specifically, because the perceived duration of the tasks increased as their physical demand increased, this study supports field observations indicating that perceived activity duration relates positively to task physical demands.[22, 27]

The work pattern can in principle have effects on both perception of the time and the estimation procedure. Intermittent work may allow for recovery from more demanding tasks,[25] therefore modifying the overall perception of the task demand. In this study, we investigated whether differences in task duration estimation between individuals executing continuous and discontinuous work were mediated through changes in the physical and cognitive demands of the tasks. We found evidence that the work pattern modified the perceived dullness of the tasks but not the heart rate ratio or the perceived physical exertion of the tasks. In the case of dullness, we found that a discontinuous work pattern was related to higher perceived dullness of the filing and shelving tasks but a lower perceived dullness of the typing task, and that dullness, in turn, was related to higher perceived duration of the tasks. This may be explained by the presence of a type of segmentation effect in which the duration of less pleasant events (shelving boxes and filing journals) that occur discontinuously tend to be overestimated via filling out the gaps between the events.[21] In the case of physical demands, we did not find important differences in the average measured or perceived physical demand of the tasks between individuals carrying out continuous and discontinuous work. Only the average heart rate ratio during the typing task was higher among individuals doing intermittent work, but this difference did not translate into higher perceived demand while doing this work.

The procedure used to estimate the total duration of the tasks may also explain the lower accuracy recorded among participants carrying out discontinuous work. When people are required to estimate the total duration of an event that is executed during multiple periods, there is a tendency to use the number of periods combined with, for example, an estimation of the average duration for each period in order to estimate the total duration of the event.[21] Therefore, the estimations of the number of periods and of the average duration of the periods are both likely to be sources of error in the estimation of the total duration. In principle, these sources of error would have influenced on average the duration perception of all tasks equally in our experiment because all the tasks were divided into the same number of periods with the same durations (4, 8, 12 and 16 min). However, neither the signed errors nor the absolute errors were clearly higher across all tasks in the discontinuous group, which suggests that, if present, errors due to estimation were not the main source of inaccuracy in this study. This finding, however, is not completely surprising because our study divided tasks into only four periods and the durations of the periods were symmetrical around the average duration (10 min) of the periods. These characteristics of the experiment could have facilitated the estimation of both the number of periods (eg, using a recall and count strategy, which would be favoured when the number of events is small[21]) and the average duration of each period.

These findings have important implications for the design and interpretation of self-report based cumulative exposure assessment and measures of association in epidemiological research. This study formally describes the direction and size of bias due to both the discontinuity of the activities of interest and the physical and cognitive demands of the activity of interest. We have documented that an overestimation of more than 30% of the time spent in a more physically demanding task (with respect to other tasks that make up the work shift) can occur when tasks are conducted in a discontinuous work pattern. Similarly, this study recorded an underestimation of over 20% of the time spent in a less physically demanding task executed discontinuously. Generally, these results suggest that the duration of exposures that occur during periods of time that are also strenuous would be overestimated; in contrast, exposures occurring during periods of time that are more pleasant or less physically demanding would be underestimated. The size of the overestimation or underestimation would be bigger when the activities of interest are executed discontinuously than when they are executed continuously.

Such errors in task duration estimation are expected to introduce considerable misclassification to task-based cumulative measures of exposure. The direction and total error in cumulative exposures will depend on the type of cumulative exposure employed. If the total duration of the task or tasks where the exposure of interest occurs is used directly as a measure of exposure,[39] then any underestimation or overestimation of the durations of tasks will reflect in the same direction and proportionally in the cumulative of exposure. If the durations of the tasks of interest are used to time-weight the magnitudes of the exposures present in each task period,[3, 6] then the direction and size of the error will depend on the association between the durations of tasks and their exposure magnitudes. Under the alternative hypothesis (ie, assuming there is a true causal effect of the exposure of interest on the outcome of interest), this exposure misclassification can result in bias of the measure of association towards the null when cumulative exposures are underestimated or away from the null when cumulative exposures are overestimated.

Although both the signed errors and absolute errors were greater in the discontinuous group, the differences between groups were more noticeable in the signed errors. This finding suggests that the discontinuity of the task had a dominant effect on the systematic error over the variable error in task duration estimation. Therefore, in planning exposure assessment, self-reported durations of activities over periods during which they are conducted continuously would reduce systematic error, while increasing the number of people estimating the duration of those periods would help in reaching more precise estimates. These findings also suggest that the exposure assessment strategies frequently used in epidemiological research that require people to allocate time or proportions of time in the work shift or day to different activities[9, 37, 40–42] may be problematic particularly if the activities differ widely (as is usually the case) in physical demands and are conducted intermittently. Overall, these findings suggest that requesting information about the duration of activities at intervals during which the activity of interest is executed continuously may help to reduce systematic bias in activity duration estimation. In this regard, our results favour the use of diaries (eg, to mark every time activity change or to report activities at regular short intervals)[27] over more simple estimation questions whenever resources or other study design constraints are favourable; this strategy would reduce bias due to both task discontinuity and/or physical demand difference between tasks. This, however, should be formally tested in future research.

These findings should be observed in the context of the study methodology. The participants of this study were volunteers who may not be representative of the working population; however, participants reported either having a current job or looking for a job, and represented both genders and a wide range of ages, heights and body masses. Our experimental approach limits the extent to which our results can be generalised to field settings. The sizes of the errors in task duration estimation are likely to differ from those observed in this study if the work characteristics are modified (eg, different tasks, with different durations, broken down differently, executed at different paces, under different environmental conditions or in the presence of other than physical exposures). Nevertheless, the focus of this study was the investigation of specific sources and mechanisms behind the accuracy of self-reported activity durations, which are likely to remain valid in modern workplaces where individuals are required to switch frequently between multiple tasks. That is, while the study results cannot be easily used to predict the size of the errors in task duration estimation in field settings (before further research is conducted on the determinants of accuracy of self-reported task durations), the observed relative bias direction is expected to apply to any pair of tasks that differ in physical or cognitive demands and/or in their execution pattern as measured in our study.

Finally, it is recommended that in designing the overall exposure assessment strategy for a study, our results should be considered along with the broader exposure assessment design aspects of the study. Our results may be used to help understand the potential mechanisms behind workers' estimation error in self-reported task durations. This information in turn may be helpful in designing self-report based strategies for task-based exposure assessment and in cautioning authors about the potential of bias in their studies when using self-reported information to estimate task durations. However, the decision on the preferred exposure assessment design and preferred instruments and sources of information should result from critical observation of the available methods and their cost, flexibility and accuracy as regards the aims of the study.[43] While a task-based approach may be appealing as it would offer the possibility of identifying the main sources of exposure (tasks) in a particular job, its cost may not be justified if achieved accuracy is not substantially better than, for example, job-based strategies.[44]

In conclusion, our findings demonstrate the dependence of self-reported activity duration accuracy on the work pattern and demands of the activity. These results suggest that cumulative exposure assessment based on self-reported information can result in bias to the measures of association of interest in any direction depending on the simultaneous demands of the tasks during which the exposure of interest occurs, and therefore these findings should be considered for exposure assessment design and for interpretation of related measures of association.

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Main messages

- Understanding the determinants of the accuracy of self-reported exposure information is crucial when evaluating the extent to which measures of association between exposure and outcome represent causal associations in occupational and environmental epidemiological research.
- The results demonstrate that task demands can affect the error in self-reported task duration estimation, and therefore these findings should be considered for exposure assessment design and for interpretation of related measures of association.

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Policy implications

Experimental, laboratory testing of self-reported data is advocated and has been proved feasible and valuable in this study for understanding better the properties of self-reported information and the circumstances under which such information is more likely to result in accurate exposure data.

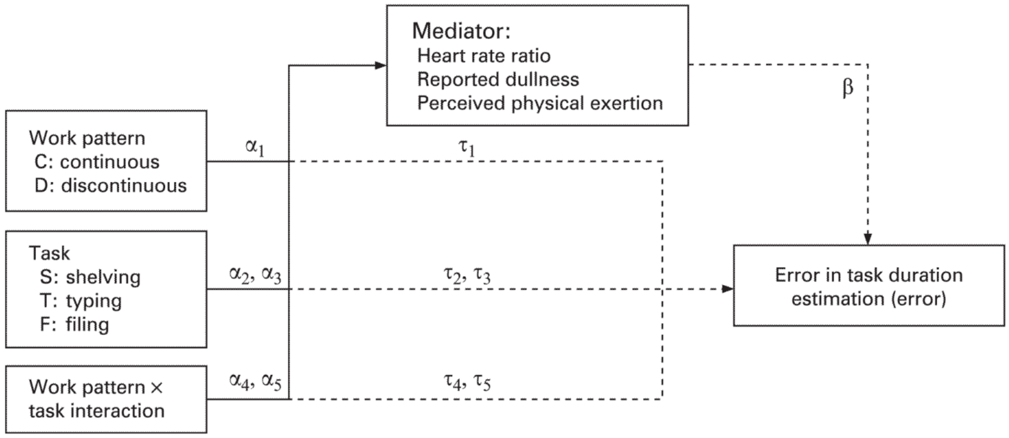

Figure 1.

Mediated moderation models of the effect of the task by work pattern interaction on the errors in task duration estimations (adapted from Morgan-Lopez and MacKinnon[33]). Separate models type 1 and separate models type 2 are created for each of the mediating variables being tested. Model 1: Expected (mediator) = $\alpha_0+\alpha_1 \cdot C+\alpha_2 \cdot S+\alpha_3 \cdot T+\boldsymbol{\alpha_4} \cdot C \cdot S+\boldsymbol{\alpha_5} \cdot C \cdot T$; model 2: Expected (error) = $\tau_0+\tau_1 \cdot C+\tau_2 \cdot S+\tau_3 \cdot T+\tau_4 \cdot C \cdot S+\tau_5 \cdot C \cdot T+\boldsymbol{\beta} \cdot M$, where C, S and T are index variables as follows: C: 1 if continuous work pattern, 0 otherwise; S: 1 if shelving task, 0 otherwise; T: 1 if typing task, 0 otherwise. Intercept parameters α_0 and τ_0 are not represented in the graph. Terms corresponding to regression parameters in bold letters ($\boldsymbol{\alpha_4}$, $\boldsymbol{\alpha_5}$, $\boldsymbol{\beta}$) are tested in mediated-moderation analysis.

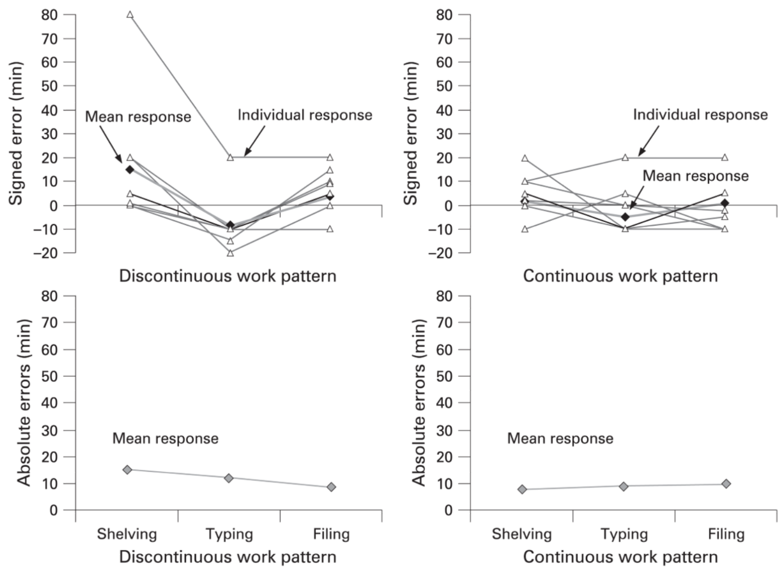

Figure 2.
Effect of work pattern and task on the accuracy of task duration perception.

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Table 1

Experimental group comparison of demographic characteristics and amount of work executed

	Continuous work pattern		Discontinuous work pattern	
Variable	**Mean (SD)**	**Range**	**Mean (SD)**	**Range**
Age	39 (10)	26–54	39 (11)	23–53
Height (m)	1.7 (0.1)	1.6–1.8	1.7 (0.1)	1.5–1.9
Body mass index	28.2 (7.0)	18–41	27.0 (5.3)	20–34
Education (years)	16.4 (2.4)	12–20	17.2 (2.6)	14–20
Amount of work				
No. of boxes	127 (23)	107–174	130 (23)	97–162
No. of articles	58 (20)	30–91	53 (18)	28–80
No. of journals	184 (18)	153–210	194 (35)	142–266

Table 2

Differences in the tested mediating variables by work pattern and task

	Dependent (mediating) variable*		
Effect	**Dullness, coeff† (SE)**	**HRR, coeff (SE)**	**PPE, coeff (SE)**
Intercept	0.58 (0.29)	0.04 (0.03)	−0.57 (0.64)
Work pattern			
Continuous (C)	−0.58 (0.41)	−0.02 (0.04)	0.58 (0.9)
Discontinuous (D)	0.0	0.0	0.0
Task			
Shelving (S)	−0.25 (0.25)	0.03 (0.02)	1.67 (0.57)
Typing (T)	−1.25 (0.3)	−0.15 (0.02)	−1.5 (0.87)
Filing (F)	0.0	0.0	0.0
Work pattern×task			
Continuous·shelving (C·S)	**0.25 (0.35)**	0.04 (0.02)	0.58 (0.81)
Continuous·typing (C·T)	**1.0 (0.43)**	−0.01 (0.03)	0.75 (1.23)
Continuous·filing (C·F)	**0.0**	0.0	0.0
Discontinuous·shelving (D·S)	**0.0**	0.0	0.0
Discontinuous·typing (D·T)	**0.0**	0.0	0.0
Discontinuous·filing (D·F)	**0.0**	0.0	0.0

*Dependent variables (mediating variables) were centered on their mean;

†regression parameters.

The table presents three separate regression models type 1 (see fig 1 and data analysis text) corresponding to each of the three mediating variables being tested in the mediated-moderation analysis. For example, the following regression model type 1 represents the expected level of dullness given the work pattern and task:

Expected (dullness) = 0.58−0.58·C−0.25·S−1.25·T+0.25·C·S+1·C·T

where C, S and T are index variables as follows:

C: 1 if continuous work pattern, 0 otherwise; S: 1 if shelving task, 0 otherwise; T: 1 if typing task, 0 otherwise.

To estimate the expected centred dullness for the filing tasks, both S and T equal 0.

To estimate the expected centred dullness for the discontinuous work pattern, C equals 0.

The marginally significant effect (p = 0.07) of the work pattern by task interaction factor on task dullness is represented in the corresponding regression parameters given in bold.

coeff, coefficient; HRR, heart rate ratio; PPE, perceived physical exertion.

Table 3

Effect of the tested mediating variables (reported dullness, heart rate ratio and perceived physical exertion) on the error in the estimation of the task durations

	Signed error		
Effect	**Coeff* (SE)**	**Coeff (SE)**	**Coeff (SE)**
Intercept	2.1 (3)	5.9 (3)	3.7 (3.1)
Work pattern			
Continuous (C)	−1.0 (4.2)	−2.9 (4.2)	−2.6 (4.4)
Discontinuous (D)	0.0	0.0	0.0
Task			
Shelving (S)	**12.1 (5.4)**	**12.7 (5.9)**	**11.3 (5.6)**
Typing (T)	**−9.0 (3.5)**	**−19.9 (4.3)**	**−12.3 (3.5)**
Filing (F)	**0.0**	**0.0**	**0.0**
Work pattern×task			
Continuous·shelving (C·S)	**−11.8 (7.7)**	**−9.6 (8.5)**	**−11.1 (7.8)**
Continuous·typing (C·T)	**3.6 (4.7)**	**5.8 (4.9)**	**6.3 (4.8)**
Continuous·filing (C·F)	**0.0**	**0.0**	**0.0**
Discontinuous·shelving (D·S)	**0.0**	**0.0**	**0.0**
Discontinuous·typing (D·T)	**0.0**	**0.0**	**0.0**
Discontinuous·filing (D·F)	**0.0**	**0.0**	**0.0**
Mediating variable†			
Dullness	**2.8 (1.2)**	NA	NA
Heart rate ratio	NA	**−50.3 (17.1)**	NA
Perceived physical exertion	NA	NA	0.1 (0.5)

*Regression parameters;

†mediating variables were centred on their mean.

The table presents three separate regression models type 2 (see fig 1 and data analysis text) corresponding to each of the three mediating variables being tested in the mediated-moderation analysis. For example, the following regression model type 2 represents the expected error in task duration estimation given the work pattern, task and reported level of dullness for each task:

Expected (error) = 2.1− 1·C+12.1·S−9·T−11.8·C·S+3.6·C·T+2.8·dullness

where C, S and T are index variables as follows:

C: 1 if continuous work pattern, 0 otherwise; S: 1 if shelving task, 0 otherwise; T: 1 if typing task, 0 otherwise.

To estimate the expected error in task duration estimation for the filing tasks, both S and T equal 0.

To estimate the expected error in task duration estimation for the discontinuous work pattern, C equals 0.

Significant effects ($p< 0.05$) of the work pattern factor, task factor or work pattern by task interaction factor by the corresponding regression parameters given in bold.

coeff, coefficient; NA, not applicable.