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Exploring the use of an under-desk leg swing device during employee aptitude testing and implications on work performance and productivity

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Abstract.
BACKGROUND: As modern occupations become more sedentary, desk-bound workers are more at risk of chronic diseases. Active workstations have gained popularity in the workplace, but there remain concerns about their impact on cognitive function.
OBJECTIVE: This study investigated the use of a novel under-desk leg swing device on cognitive ability in the workplace compared to sitting.
METHODS: Cognitive ability was measured using a pre-employment aptitude test (CCAT), and perceived outcomes were analyzed via self-report questionnaires. Using a randomized, repeated measures crossover design, 18 undergraduate students undertook the CCAT while using the under-desk leg swing device and while sitting only (Experiment 1). 9 students returned two to three weeks later to repeat testing (Experiment 2).
RESULTS: In Experiment 1, CCAT scores did not differ significantly between the under-desk leg swing device and sitting (mean difference (MD) = –1.056, standard error (SE) = 1.302, $p = 0.429$, d = –0.16). Effect sizes of 0.554 were observed for perceived alertness, 0.446 for attention, 0.446 for focus, and 0.564 for enjoyment, but there were no significant differences between the two conditions. CCAT scores were significantly higher in Experiment 2 than in Experiment 1 (MD = 8.444, SE = 2.410, $p = 0.008$, d = 1.64).
CONCLUSION: Based on Experiment 1, the findings suggest that the use of the under-desk leg swing device promotes movement without detriment to neither workflow nor cognitive ability relevant to employee aptitude compared to sitting.

Keywords: Active workstation, office ergonomics, sedentary behavior

1. Introduction

Given the sedentary nature of most modern occupations [1–3], working adults are sitting more than ever before, with office workers spending more than 70% of their workday seated [4–6]. Such sedentary behavior has been linked to adverse health effects, including obesity, depression, type II diabetes, and symptoms of musculoskeletal disorders, as well as greater risk of all-cause mortality [7–13]. This creates an explicit challenge for employers, since prolonged sitting has also been associated with decreased work performance, poorer mental health status, and more illness-related absenteeism [14–16].

The current physical activity guidelines provided by the World Health Organization propose 150 to 300

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minutes per week of moderate exercise [17], but some research has shown that even more is required to offset the consequences of a sedentary workday (420 to 525 minutes per week) [18]. Today, the health benefits of physical activity, especially at moderate to vigorous intensities, are indisputable among epidemiologists and public health researchers [19, 20]. However, recent research is also recognizing the importance of brief but frequent bouts of exercise to interrupt prolonged periods of sitting [21–23]. As a result, hourly 5-minute walking breaks are often advised by workplace health practitioners [24]. Yet, depending on the occupation and type of task, these microbreaks could cause work fragmentation due to the disruption of workflow. For example, financial and information technology analysts took an average of 25 minutes to resume work after an interruption [25].

As public awareness of the health risks associated with a sedentary lifestyle continues to spread, the demand for ergonomic solutions in the workplace has also grown. Most notably, this demand has led to the development of a variety of active workstations, such as the sit-stand and standing desks, treadmill and cycling workstations, and under-desk ellipticals. The aim with all of these innovations is the same—to encourage physical activity among desk-bound workers without creating any interruption to workflow—but striking a balance between enabling appropriate physical activity levels and maintaining work performance comparable to a traditional sitting workstation is complicated, as evidenced by the many existing studies on the relationship between active workstations and workplace productivity.

In light of the detriments of prolonged sitting, the suggestion to replace occupational time spent sitting with standing through the use of sit-stand desks and standing desks became popular. The reasoning behind this suggestion was that maintaining an upright posture engages the body's postural stability muscles to a greater extent than sitting [26], thus increasing energy expenditure. Although there is evidence to support this claim [27, 28], the difference is relatively small, and significant differences were predominantly observed in only obese and overweight adults [29]. Besides, researchers have since determined that the perils of sedentary behavior stem from habitually low levels of energy expenditure—both sitting and standing postures are insufficient to attenuate the health risks associated with sedentary behavior [21, 22].

Treadmill desks and cycling workstations have been shown to significantly increase energy expenditure compared to traditional workstations, even in healthy adults [30]. However, the current literature regarding the impact of these workstations on cognitive function and work performance is inconclusive. Some researchers have reported no difference in work performance during either treadmill or cycling interventions [31–34]; others have detected reductions in attention, processing speed, learning and memory, and mathematical problem solving, in addition to declines in fine motor skills, including typing and mousing [35–38]. There is little evidence, thus far, concerning under-desk ellipticals, but the existing literature seems to suggest that under-desk pedaling also adequately increases energy expenditure [28, 39]. In a case study exploring the use of under-desk ellipticals in an office setting, participants indicated preferring to pedal only when taking breaks or performing simple tasks [40]; the authors did not provide an explanation, but it is possible that the interdependence between the arms and legs during cyclical movements made it difficult for participants to coordinate their arms while pedaling, preventing them from carrying out more complex office tasks [41]. This phenomenon has also been observed in individuals using cycling workstations [42].

In response to these challenges, a new type of active workstation was developed in the form of an under-desk leg swing device. Despite the unique form factor, research has already shown significant increases in energy expenditure when using this ergonomic device ($\approx$ 1.4 metabolic equivalents [METs])—between 15% and 20% higher than sitting ($\approx$ 1.2 METs) and 7% higher than standing ($\approx$ 1.3 METs) [43, 44]. Furthermore, another study examined the potential impact of the under-desk leg swing device on cognitive function and found no differences in vigilance and mental attention when compared to a traditional sitting workstation or a standing desk [45]. These initial reports are encouraging, as the optimal workstation for office-bound workers remains unclear. Thus, the aims of the present study are to further investigate the influence of the under-desk leg swing device on cognitive ability in the workplace using a pre-employment aptitude test (Experiment 1) and to examine participants' perceptions while using the device after extended exposure (Experiment 2). Cognitive ability relevant to employee aptitude, as well as the participants' perceived alertness, attention, focus, and enjoyment while using the device, are compared to the traditional sitting workstation. It was hypothesized that cognitive ability and the perceived outcomes would not be impaired when using the under-desk leg swing device compared to sitting only in Experiment 1 and Experiment 2. Likewise, it was hypothesized that cognitive ability and the perceived outcomes would be greater in Experiment 2 compared to Experiment 1 due to increased exposure with the under-desk leg swing device. Since previous studies on active workstations and workplace productivity were focused largely on computer-based performance metrics (typing speed and errors), the findings from the present study could offer valuable insight into workplace performance in more advanced and technical contexts.

Fig. 1. The under-desk leg swing device (SitFlow, Active Ideas LLC).

2. Methods

2.1. Participants

A convenience sample of 18 healthy, senior-level undergraduate students (11 males and 7 females) attending the California Polytechnic State University was recruited via word of mouth and included only students who were compliant with the university's COVID-19 testing program. None of the participants reported any cognitive or intellectual impairments or any previous experience with mobile footrests, and all of the students were enrolled in either a science- or engineering-related major. Prior to testing, participants were given both a verbal and written explanation of the experimental procedure, and informed consent was obtained from all participants. This study and the written consent form were approved by the Institutional Review Board.

2.2. Instruments

An under-desk leg swing device called SitFlow (Active Ideas LLC, Chicago, IL, USA) was used in this study. The device is anchored to the underside of a desk and suspends from a strap, allowing the footrest to swing freely (Fig. 1). There are separate, rubberized pads for each foot on either side of the footrest. The device engages the lower limb muscles by prompting pendulum-like movements across multiple planes, as well as some rotational movement.

2.3. Procedure

A randomized, repeated measures crossover design was adopted for this study. The experimental procedure was divided into two parts: Experiment 1 and Experiment 2 (two to three weeks apart); the first experimental session (Experiment 1) included all 18 participants, 9 of whom returned for the second session (Experiment 2).

In the first experimental session, participants performed both testing conditions (in randomized order) on the same day. For the under-desk leg swing condition, participants were provided with verbal and written instructions on how to properly use the device, in addition to a tutorial video. Then, participants engaged in a familiarization period with the device (approximately 5 minutes), including an opportunity to ask questions. For both conditions, participants were provided with information regarding the pre-employment aptitude test that they would be taking. The traditional workstation was put together using a desk and chair combination that is typically found in the college's lecture halls. For the sitting condition, participants were also given time to relax or ask questions to standardize the amount of time before each testing condition (approximately 10 minutes). During testing, participants undertook a pre-employment aptitude test twice, once while using the under-desk leg swing device and once while sitting at a traditional workstation. Each testing condition lasted 15 minutes, and between the two conditions, participants took a 5-minute break to rest, drink water, or use the washroom. After finishing the second testing condition, participants were asked to complete a questionnaire to gather information about their experience with the under-desk leg swing device.

The procedure for the second experimental session was exactly the same as the first session. Despite already having familiarized with the under-desk leg swing device, participants were allotted another familiarization period to standardize the experimental procedure. As in the first session, the order in which the participants performed the two conditions was randomized. At the end of testing, participants filled out another questionnaire with additional questions to compare their experiences in Experiment 1 and Experiment 2.

2.3.1. Measurement of cognitive ability

The participants' cognitive ability was measured using a validated and standardized pre-employment aptitude test called the Criteria Cognitive Aptitude Test (Criteria Corp., West Hollywood, CA). The CCAT consists of 50 multiple-choice questions formulated to assess problem solving, learning ability, critical thinking, and attention to detail. The test is administered in 15 minutes, but participants are not expected to finish all 50 questions within this time frame. Participants were given hard copies of two equivalent but different versions of the CCAT to be completed by hand during each testing condition. The same two versions of the test were re-administered in Experiment 2. The raw scores (out of 50) from both tests were calculated for each of the participants.

2.3.2. Measurement of perceived outcomes

A post-experiment questionnaire was designed to collect qualitative data about the participants' initial experiences using the under-desk leg swing device, including their perceived alertness, attention, focus, and enjoyment during the testing conditions. To measure these perceived outcomes, the participants were asked (using a 5-point Likert scale, except for enjoyment, which used a 3-point Likert scale) if their experiences differed between the two conditions. Participants were also invited to give open answers to explain their responses and to offer their opinion on the user experience of the under-desk leg swing device. For the returning 9 participants, the questionnaire for Experiment 2 included additional questions asking them to compare their experiences and perceived outcomes between the two experimental sessions.

2.4. Data analysis

Statistical analyses were performed using SPSS v25 (IBM, Armonk, NY). Assumptions of data normality and equal variances were tested with the Shapiro-Wilk test and Levene's Test for Equality of Variances, respectively. Participants' cognitive ability, as represented by their raw scores on the CCAT, were compared between the under-desk leg swing condition and the sitting condition. For Experiment 1 ($n = 18$), a paired t-test was used to compare the CCAT scores between the two conditions. In addition, a two-way ANOVA was also used to determine the potential of an order effect (i.e., a significant interaction effect between intervention type [under-desk leg swing device or sitting] and sequence [first or second testing condition]), as was observed by Horswill et al. [43]. Nine participants returned for Experiment 2. A three-way ANOVA was used to evaluate whether there was a significant main effect for experimental session (Experiment 1 or Experiment 2) and whether there were significant interactions between intervention type, sequence, or experimental session. In the case of a significant main effect for experimental session, a paired t-test was used to compare the CCAT scores from only the first testing conditions in Experiment 1 and Experiment 2. Initial responses from the post-experiment questionnaire regarding perceived outcomes were pooled (unchanged perceptions were excluded), and Fisher's exact tests were used in Experiment 1 to establish the significance of the participants' collective experience with the under-desk leg swing device compared to the traditional sitting workstation using a 3-point Likert scale for enjoyment (1 = decreased; 2 = increased; and 3 = unchanged) and a 5-point Likert scale for alertness, attention, and focus (1 = greatly decreased; 2 = decreased; 3 = unchanged; 4 = increased; and 5 = greatly increased). Only descriptive statistics were analyzed in Experiment 2 (relative frequencies [RF]). Any open answers that were relevant to the potential outcomes of the study were considered when interpreting the study's findings. Effect sizes were also calculated: Cohen's d for cognitive ability and Cramer's V for the perceived outcomes. Cohen's d effect sizes were treated as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79), and large (>0.80) [46], whereas Cramer's V effect sizes were interpreted as small, medium, or large depending on the degrees of freedom (for df = 2, small ≤ 0.07, medium ≤ 0.21, large ≤ 0.35; for df = 4, small ≤ 0.05, medium ≤ 0.15, large ≤ 0.25) [47]. Statistical significance was set at $p < 0.05$.

3. Results

3.1. Cognitive ability

The paired t-test showed no statistical difference in CCAT scores between the under-desk leg swing condition and the sitting condition during the first experimental session ($p = 0.429$; d = –0.16). The two-

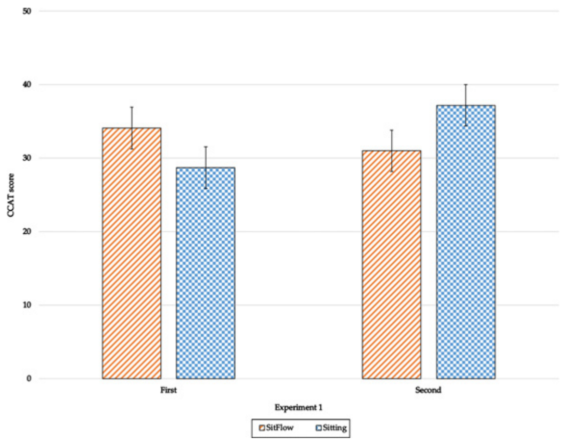

Fig. 2. Results of the CCAT from the first and second testing conditions in Experiment 1. Data are presented as means and standard errors (SitFlow: diagonal lines; Sitting: checkerboard).

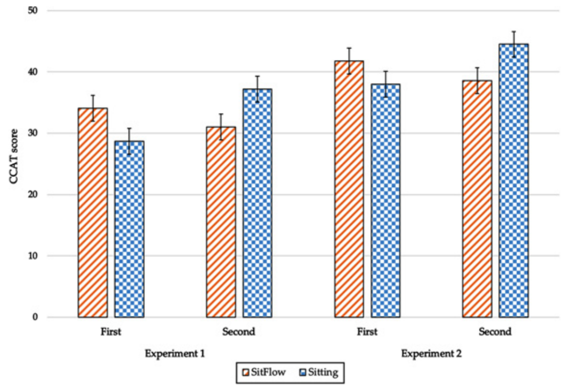

Fig. 3. Results of the CCAT from the first and second testing conditions in Experiment 1 and Experiment 2 (returning participants only). Data are presented as means and standard errors (SitFlow: diagonal lines; Sitting: checkerboard).

way ANOVA on the effects of intervention type and sequence on cognitive ability (CCAT score) revealed no interaction ($p = 0.177$; d = 0.17) but a statistically significant main effect for sequence (F (1,32) = 8.404; $p = 0.007$; d = 1.04). Figure 2 presents the results of the CCAT from both testing conditions and sequences in Experiment 1.

3.2. *Perceived alertness, attention, focus, and enjoyment*

Fisher's exact tests were used to assess the participants' experiences with the under-desk leg swing device across the four perceived outcomes and between those who used the device in the first testing condition (i.e., those who sat second) and those who used the device in the second testing condition (i.e., those who sat first) during the first experimental session. There were no statistically significant associations between testing condition and any of the perceived outcomes, but there were large effect sizes for all outcomes. The participants who used the under-desk leg swing device in the first testing condition reported more alertness (38.89% vs. 22.22%; $p = 0.224$; V = 0.554), equal attention (22.22% vs. 22.22%; $p = 0.646$; V = 0.446), less focus (22.22% vs. 27.78%; $p = 0.677$; V = 0.446), and less enjoyment (27.78% vs. 38.89%; $p = 0.070$; V = 0.564) compared to the participants who sat in the first testing condition. Two participants who used the device in the first testing condition provided open answers. One mentioned that when moving their legs, the desk made squeaking noises which took away from their ability to focus; the other attributed some loss of focus to notification alerts from their cell phone.

3.3. *Subsequent analysis*

The three-way ANOVA on the effects of intervention type, sequence, and experimental session on cognitive ability (CCAT score) showed no significant interactions, but there was a statistically significant main effect for experimental session (F (1,28) = 13.020; $p = 0.001$; d = 1.14). Figure 3 presents the results of the CCAT from both testing conditions in Experiment 1 and Experiment 2. On account of this main effect, a paired *t*-test comparing the CCAT scores between the two experimental sessions was performed. In this case, equal variances were assumed. As shown in Figure 4, participants scored significantly higher CCAT scores in Experiment 2 compared to Experiment 1 (MD = 8.444; SE = 2.410; t(8) = –3.504; $p = 0.008$), and a large effect size was observed (d = 1.64).

Descriptive statistics were used to explore the participants' experiences with the under-desk leg swing device between the first and second experimental sessions. In Experiment 2, the majority of participants reported unchanged or increased perceived alertness (RF% = 88.89% vs. 11.11%), attention (RF% = 88.89% vs. 11.11%), focus (RF% = 77.78% vs. 22.22%), and enjoyment (RF% = 66.67% vs. 33.33%) compared to Experiment 1. In the open answers, two of the participants noted complaints about the workstation setup; five stated feeling more comfortable with the under-desk leg swing device

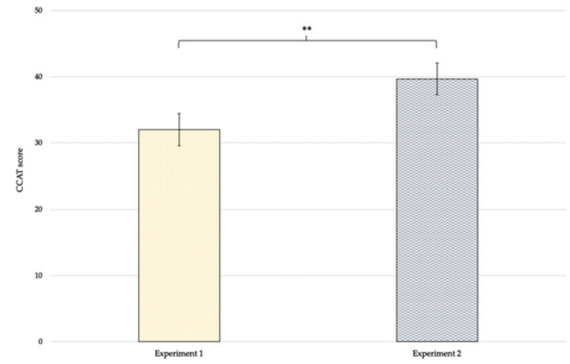

Fig. 4. Results of the CCAT from only the first testing conditions in Experiment 1 and Experiment 2 (returning participants only). Participants scored significantly higher in Experiment 2 compared to Experiment 1 ($p = 0.008$, denoted by **). Data are presented as means and standard errors.

in Experiment 2 compared to Experiment 1, which increased their enjoyment.

4. Discussion

The purpose of this study was to investigate the use of an under-desk leg swing device during employee aptitude testing compared to the traditional sitting workstation, and subsequently, to analyze the implications on work performance and workplace productivity using a pre-employment aptitude test. Furthermore, this research sought to explore the participants' perceived alertness, attention, focus, and enjoyment while using the device. The main finding of this study indicates that CCAT scores did not differ when participants used the under-desk leg swing device compared to sitting.

This study also included an exploration of the potential associations between testing condition and perceived alertness, attention, focus, and enjoyment. Large effect sizes were observed in all four of the perceived outcomes, suggesting strong associations that are dependent on whether the participants used the under-desk leg swing device first (i.e., sat second) or used the device second (i.e., sat first). The rationale behind comparing the effect of testing condition was based on the fact that participants were using the under-desk leg swing device for the very first time during the first experimental session (regardless of whether in the first or second testing condition), affording the authors an opportunity to examine the participants' initial experiences with the device. Despite the non-statistically significant difference, participants in this study reported a tendency for increased perceived alertness when using the under-desk leg swing device compared to sitting at a traditional workstation. Our findings, though based on self-report data, complement the results from a previous study which showed that vigilance and mental attention were undisturbed when participants performed an objective test of attention while using the device (compared to sitting) [45]. In cognitive psychology, vigilance and alertness are typical metrics of cognitive function, where vigilance is used to measure sustained attention during long and mundane tasks, and alertness is tied to increased states of arousal [48], which has been previously associated with exercise [49]. Both of these metrics are equally relevant when considering the implications of the under-desk leg swing device on work performance and workplace productivity and should be objectively measured in a future study.

The associations observed in Experiment 1 were helpful to contextualize the relative frequencies calculated for the perceived outcomes in Experiment 2. Due to the small sample size and the paired nature of the data, the authors decided to report the potential associations between testing condition and perceived outcomes as descriptive statistics, since the appropriate statistical tests are only recommended for independent data or larger samples (Fisher's exact test or Bowker's test) [50–52]. In Experiment 2, more than two thirds of the returning participants reported unchanged or increased alertness, attention, focus, and enjoyment compared to Experiment 1. Taking into account the open answers, and given that higher CCAT scores were achieved in the second experimental session compared to the first, the results from the post-experiment questionnaires suggest that after sufficient familiarization, the addition of the under-desk leg swing device could offer perceived cognitive benefit during an assessment of pre-employment aptitude. Further research is warranted based on this preliminary data. It was the authors' intention to generalize the findings from this study on the influence of the under-desk leg swing device on cognitive ability to consider the implications of using the device in an office setting. To this end, the CCAT was selected as the measure of cognitive ability based on the available literature supporting the predictive validity of cognitive aptitude tests on job performance [53, 54]. Short of a field study, this work offers valuable insight into the implications of using the under-desk leg swing device on work performance and workplace productivity, especially in specialized occupations that rely on higher-level executive function.

The purpose of Experiment 2 was to determine if more familiarization with the under-desk leg swing device would influence cognitive ability and perceived outcomes. It should be noted that participants were given the same two versions of the CCAT at both experimental sessions (two to three weeks apart). Having two equivalent versions of the test was a strength of this study and provided equivalent forms reliability in Experiment 2, but it is possible that potential practice effects may have occurred in Experiment 2. Still, the higher scores recorded in Experiment 2 align with the participants' open answers, where the majority of returning participants reported feeling more comfortable with the under-desk leg swing device in Experiment 2 compared to Experiment 1. In this way, the findings of the study suggest that the under-desk leg swing device could contribute to perceived cognitive benefit during an assessment of employee aptitude.

5. Limitations

There are some limitations to consider when interpreting the results of this study. Due to the public health restrictions in place amid the COVID-19 pandemic, the recruitment of participants was limited in regard to both the size and homogeneity of the sample group. It was also unfeasible to carry out the experimental procedure over two separate days, so the participants completed both testing conditions on the same day. Given the short break between the two testing conditions, a main effect for sequence and experimental session was observed in Experiment 1 and Experiment 2, respectively. Future research should ensure a longer break is given between testing conditions, preferably not on the same day, and different (but equivalent) versions of the CCAT should be used for subsequent analyses.

While the present study measured the perceived outcomes using a Likert scale and open questions, objective measures of alertness, attention, and focus should be considered in a future study, especially over a longer period of time where participants can further familiarize themselves with the under-desk leg swing device. It is also worth mentioning that although this study was not able to control for potential between-subject differences (e.g., Intelligence Quotient [IQ] or Grade Point Average [GPA]), the participants belonged to a rather homogenous group, and on average, scored 13 points higher on the CCAT than the test's standardization sample [55]. In future research, it would be of interest to analyze the use of the under-desk leg swing device among a large group of healthy adults with diverse IQ scores. Of further interest would be a field study evaluating the routine use of the under-desk leg swing device that ensures a representative sample of desk-bound workers in an office setting.

6. Conclusions

The present study contributes new evidence to the body of knowledge on active workstations as the first to examine the influence of a novel under-desk leg swing device on cognitive ability relevant to employee aptitude. Our findings suggest that the use of the under-desk leg swing device does not negatively impact cognitive ability relevant to employee aptitude when compared to sitting at a traditional workstation. Furthermore, perceived alertness, attention, focus, and enjoyment are improved, granted the users are sufficiently familiar with the device. More research on the under-desk leg swing device beyond the laboratory setting is necessary to assess the everyday implications on work performance and workplace productivity during cognitively demanding office tasks. Future studies will also require more objective measures of work satisfaction, fatigue, and other related factors to inform meaningful and actionable recommendations on the full-fledged adoption of the under-desk leg swing device in the workplace. In the meantime, these data offer workplace health practitioners a promising alternative workstation in their search for an ergonomic solution that promotes movement without detriment to workflow.

Acknowledgments

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Ethics approval

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of the California Polytechnic State University (March 15 2021).

Informed consent

Informed consent was obtained from all subjects involved in the study.

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Conflict of interest

H.L. was involved as a consultant to Active Ideas LLC. The funding agency had input into the design of the study, but no role in the collection, analyses or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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