Does the Duration of Breaks in Learning Sensorimotor Tasks Influence Performance? – An Age-Differentiated Laboratory Study

Francoise Kuhlenbaeumer
RWTH Aachen

Simone Polis
RWTH Aachen

Philipp Przybysz
RWTH Aachen

Susanne Muetze-Niewoehner
RWTH Aachen

For investigating the influence of breaks on the learning time of sensorimotor tasks, a laboratory study with 48 participants in two age groups was conducted. The experimental task was the repeated assembly of a gear. After each trial participants had a break with different duration, depending on the experimental condition which varied in four values. To evaluate the performance, execution times and assembly errors of each trial were measured. The results show significant learning effects and a significant difference between the execution times of both age groups. No significant difference was found between the age groups concerning assembly errors.

INTRODUCTION

In times of customer-oriented production and short product lifecycles, working persons often have to execute new or changed tasks. In assembly areas, tasks usually require sensorimotor skills, which have to be learned task-specific (Rohmert, Uhlich & Rutenfranz, 1974; Stark-Inbar et al., 2017). Consequently, these working persons have to get to know each new task and train it before they are able to execute the task achieving the required performance. The associated period is referred to as learning time and must be considered in scheduling activities in order to prevent missed deadlines of production start-up processes.

In previous age-differentiated studies it was shown that age group as well as different learning conditions influence the learning performance. The studies examined whether task descriptions and methods of introduction into the new task had an effect on learning sensorimotor tasks. In both studies, learning times significantly differed between the age groups. Execution times of older participants were higher than the execution times of younger participants. However, a different pattern emerged for assembly errors depending on introduction method. Hence, optimal learning conditions vary between younger and older persons.(Kuhlenbäumer et al., 2017; Kuhlenbäumer, Przybysz & Mütze-Niewöhner, 2018).

Learning performance is also dependent on other organizational elements such as break periods (Jeske, 2013; Schlick, Bruder & Luczak, 2010). The advantages of breaks during learning include countering central and muscular fatigue, relaxing effects, motivational aspects of the break and the possibility for mental training (Iskander, 1968; Hacker & Skell, 1993). However, with increasing duration of the break forgetting effects set in and performance decreases (Iskander, 1968; Hacker & Skell, 1993; de Greiff, 2001; Globerson, Levin & Shtub, 1989). Single breaks up to a duration of 30 minutes were experimentally determined as limiting value for the positive influence of breaks on learning outcome (Iskander, 1968). The same study showed that the impact of breaks on performance decreases with rising duration of breaks. This however was only investigated for short break periods of 30, 60, 90 and 120 seconds.

In order to further investigate the influence of breaks and to extend the original model (Stark-Inbar et al., 2017), the presented study evaluates how the duration of breaks influences learning time of younger and older participants. Since the literature does not yet provide a maximum duration for breaks to achieve a positive influence on the learning of sensorimotor tasks, it is of particular interest, which relations exist between the duration of breaks and learning outcome on the one hand and the subjectively perceived workload on the other hand. According to our previous studies, it is also interesting to see how far a possible age effect affects the learning output and the subjectively perceived workload.

For this purpose, a laboratory study with an age-differentiated sample was conducted. The chosen durations of breaks were 2, 4, 8 and 16 minutes.

METHODOLOGY

A. Participants

A total of 52 right-handed participants took part in this study. However, four female participants were not able to cope the experimental task. As a consequence, only 48 participants were included in the analysis, divided into two gender-balanced age groups of equal size: AG I included participants from 20 – 35 years of age, AG II participants from 52 – 67 years. The average age of AG I was 24.50 (± 3.176) years and of AG II 60.83 (± 4.260) years.

B. Experimental Task and Setup

The experimental task was the repeated assembly of a 2-stage helical gear unit at a standardized, seated workplace. The gear unit consists of 31 components like housing, shafts and bearings but also screws and circlips. With the exception of the gear unit housing, all components were provided in a standardized way in open fronted storage boxes in front of the participant's workplace. Due to the weight of the gear unit housing, it was placed in a transfer station, from where participants could pull it into the work area and push the completely assembled gear unit back. Time measurement was conducted using a light barrier system installed at the transfer station.

As tools, two circlip pliers, a spanner and an Allen key were provided at standardized positions in a tool holder at the right side of the workplace. The introduction consisted of a text- & figure-based task description. This task description showed the spatial arrangement of the components of the gear unit in three figures based on CAD-data. Each figure was supplemented by textual hints that should draw participants' attention and support participants at difficult assembly steps. The task description was presented on a touch screen placed on the left side of the workplace. Following each assembly, participants had a break. The duration of the break depended on participants' experimental condition. Within this break, participants received standardized feedback about assembly errors that occurred in the previous assembly. Afterwards participants were allowed to read magazines, eat and drink or use their mobile phones, but not to touch components of the gear unit or use the tools.

C. Experimental Variables

Participants were randomly assigned into four groups (duration of break: 2, 4, 8, and 16 minutes). Age group with two levels (AG I, AG II) and duration of break with four levels (2, 4, 8, 16 minutes) were chosen as independent variables. In order to evaluate the performance of participants, execution times and assembly errors in each trial were chosen as dependent variables. Assembly errors were errors that remained in the finish assembled gear unit. Errors, which occurred during the assembly and were corrected by the participant immediately, are indirectly represented because they result in longer execution times. A further dependent variable was the subjectively perceived workload, which was determined with the NASA Task Load Index (Hart & Staveland, 1988).

The circadian rhythm, the self-evaluated experience with assembly and gear units, the fine motor skills, the spatial imagination, the retentiveness and the technical comprehension of the participants were collected as control variables. This was made by means of the following tests: a fine motor skill test (Schoppe, 1974; Neuwirth & Benesch, 2004), three subtests (spatial imagination "cubes", verbal and figural retentiveness) of the intelligence structure test (I-S-T 2000R, German version, (Griefahn et al., 2001)) and a subtest (technical comprehension) of the AZUBI-TH (Yörlich & Schuler, 2007), a German test to control the vocational aptitude for technical occupation. The German version of Morningness Eveningness Questionnaire (D-MEQ) was used to evaluate participants' circadian rhythm. However, most participants' circadian rhythm was intermediate (AG I: 87.5%; AG II: 66.7%) on the scale 'definite evening', 'moderate evening', 'intermediate', 'moderate morning', 'definite morning'. Due to the low level of differentiation, this control variable will not be considered.

D. Procedure

Upon arrival each participant was informed about the study and the rights as a participant. In order to collect the control variables, the participant had to complete a demographic questionnaire and the above-mentioned tests.

Afterwards, the participant was introduced to the workplace during the experiment and an ergonomic working position was ensured by adjusting the seat to the body height of the participant.

Before the main test started, the participant was informed about the main aspects of the experimental tasks. This included an explanation of the use of the touch screen and an explanation of error feedback as well as safety instructions regarding the weight of some components. Due to the use of circlips, the participants had to wear protective goggles throughout the assembly.

Participants in the 16 minutes break condition executed the experimental task 5 times whereas all other participants repeated the task 10 times.

As a post-test, the NASA Task Load Index (Hart & Staveland, 1988) followed after the final trial to evaluate the subjective workload of the participants.

E. Statistical Analyses

The analyses were conducted with IBM SPSS Statistics 23. Execution times as well as errors of single trials and the subjectively perceived workload were analyzed with two-way ANOVAs. Repeated measured ANOVAs were used to analyze changes in performance due to repeated execution of the experimental task. Besides homoscedasticity all assumptions for applying the chosen statistical analysis were met. Violations of sphericity were corrected with Greenhouse-Geisser. Pairwise comparisons with Bonferroni adjustment were used as post hoc tests. Correlations between ordinal data were analyzed with Spearman's correlation coefficient, whereas all other correlations were analyzed with Pearson's correlation. The chosen level of significance was $\alpha = 0.05$ (Field, 2009).

RESULTS AND DISCUSSION

A. Characteristics of Participants

The majority of participants had none or little experience with assembly and gear units. A few participants stated their experience with assembly as medium or high. None of the participants evaluated his experience with gear units as high. Significant differences concerning the self-evaluated experiences do not exist between the age groups.

In spatial imagination, participants in AG I identified on average 13.29 (± 3.445) cubes out of 20 cubes correctly whereas participants in AG II identified on average 8.75 (± 3.505) cubes correctly. Participants in AG I answered 11.58 (± 2.873) questions and participants of AG II 9.63 (± 3.294) questions out of 16 technical questions correctly in the AZUBI-TH. Concerning the retentiveness, participants in AG I remembered 8.33 (± 2.078) words out of 10 words and 9.58 (± 2.448) figures out of 13 figures. Participants in AG II remembered 6.58 (± 2.205) words and 7.39 (± 2.169) figures. The results of the fine motor test series are given in TABLE 1, which shows the T-values of the six Fleishman-factors according to Schoppe (Schoppe, 1974; Fleishman, 1972; Fleishman & Ellison, 1962).

TABLE 1
PARTICIPANTS' MOTOR SKILLS (GIVEN IN T-VALUES WITH STANDARD DEVIATION)

	AG I	AG II
Factor 1	53.56 (± 4.548)	55.25 (± 2.850)
Factor 2	51.67 (± 8.281)	53.13 (± 8.040)
Factor 3	52.71 (± 7.111)	48.42 (± 7.150)
Factor 4	61.00 (± 3.121)	55.83 (± 7.081)
Factor 5	51.96 (± 7.232)	43.25 (± 4.901)
Factor 6	53.00 (± 8.465)	40.92 (± 8.924)

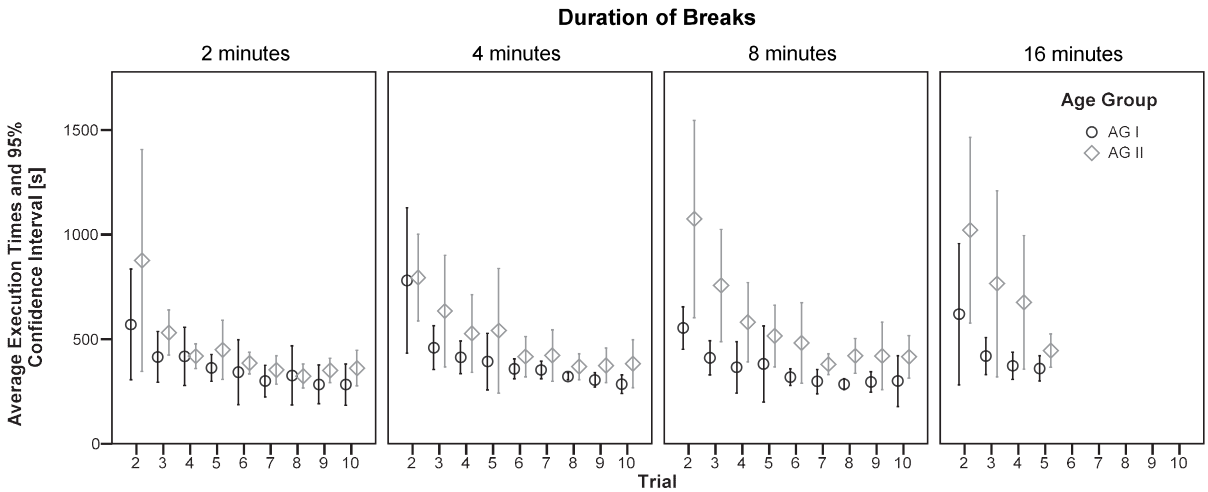
Values in the range of 50±10 indicate normal motor skills

B. Execution Times

Figure 1 shows the average execution times and 95% confidence intervals of both age groups depending on the duration of the break. Execution times of the first trials are not presented in the figure because of very large confidence intervals and much higher execution times compared to the execution times of the second trial. On average participants needed 2826.173 s (± 1368.829 s) for the first trial and 786.532 s (± 370.684 s) for the second trial.

The statistical analyses of the first execution time show a significant difference ($F_{(1; 40)} = 23.832$; $p < 0.001$) between the first execution times of participants in AG I (M = 2042.737 s; SD = 1123.196 s) and AG II (M = 3609.610 s; SD = 1134.179 s). As expected, no significant main effects or interactions concerning the duration of breaks were found for the first trial. Decreasing execution times with rising number of trials can be observed with respect to all ten/five trials. However, the differences between consecutive execution times also decrease with rising number of trials. Consequently, it seems that the execution times converge to a limiting value. These observations indicate a learning effect. The execution times of participants in AG II are higher in every trial than the execution times of participants in AG I.

FIGURE 1
AVERAGE EXECUTION TIMES OF BOTH AGE GROUPS DEPENDING ON THE DURATION OF BREAKS



This difference seems to be lower in the experimental conditions 2 and 4 minutes than in the experimental conditions 8 and 16 minutes. Thus, the difference between the execution times of participants in AG I and AG II increase with longer breaks. For the first five trials the results of a repeated measured ANOVA indicated a significant main effect ($F_{(1.204; 48.167)} = 197.182$; $p < 0.001$) of repeated execution on the execution time. Pairwise comparisons indicate significant differences between the execution times of the first and second trial and all following trials as well as a significant difference between the execution time of the third trial and the execution time of the fifth trial.

These differences decrease with rising number of trials. Thus, the observed learning effect is shown for the first five trials. Furthermore, a significant interaction ($F_{(1.204; 48.167)} = 17.703$; $p < 0.001$) was found between the repeated execution and the age group on execution time. Overall, the execution times are significantly ($F_{(1; 40)} = 32.042$; $p < 0.001$) higher for participants in AG II than the execution times of participants in AG I. In a further ANOVA the trials 5 to 10 were analyzed for the experimental conditions 2, 4 and 8 minutes. This analysis also revealed the repeated execution ($F_{(2.249; 67.459)} = 11.095$; $p < 0.001$) and the age group ($F_{(1; 30)} = 10.459$; $p = 0.003$) as significant main effects.

The associated post hoc test identifies significant differences between execution times until the sixth trial. That means participants had significant performance improvements until the sixth trial. The age group is also a significant main effect $F_{(1; 30)} = 10.459$; $p = 0.003$) in the trials five to ten.

C. Correlations Between Execution Times and Participants Characteristics

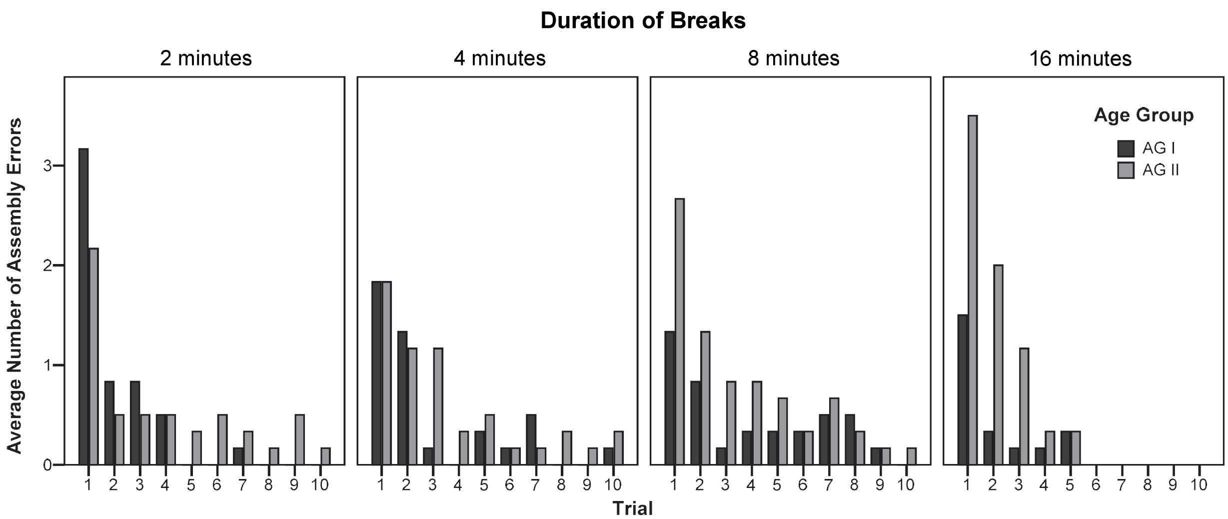
The analyses of correlations between participants' characteristics and execution times were carried out separately for each age group. There were no significant correlations between execution times and the verbal retentiveness as well as between execution times and the Fleishman factors 1, 2, 4 and 6. However, in AG II figural retentiveness and the Fleishman-factors 3 and 5 correlate significantly with one of the repeated execution times. It is reasonable to assume that these three correlations are statistical artefacts, therefore it is suggested that retentiveness and fine motor skills do not influence the execution time.

In both age groups the first execution time correlates with gender, experience with assembly and technical comprehension. Thus, female participants needed more time for the first execution than male participants. More experience with assembly and a better technical comprehension result in lower execution times of the first trial. Additionally, the first execution time is lower when participants in AG I have more experience with gears and when participants in AG II have a lower age. In further trials, execution times correlate negatively in both age groups with the experience with assembly. Furthermore, negative correlations were found for participants in AG I between some execution times and experience with gears, spatial imagination, and technical comprehension.

D. Assembly Errors

The average numbers of assembly errors are depicted depending on the duration of break for both age groups in Figure 2. Although it seems that differences exist between the number of errors and different experimental conditions in the first trial, no significant differences were found in the statistical analysis. With regard to assembly errors, there exists no performance difference between the different experimental groups before the duration of break comes into effect. With rising number of trials the number of assembly errors decreases. As already discussed with regard to the execution times, this indicates a learning effect, which is statistically significant ($F_{(1.759;\ 70.361)} = 25.413$; $p < 0.001$). Significant differences between the numbers of errors of different trials can be detected until the second trial. Significant differences between the number of errors of participants with different durations of breaks or participants that belong to different age groups do not exist.

FIGURE 2
AVERAGE NUMBER OF ASSEMBLY ERRORS OF BOTH AGE GROUPS DEPENDING ON THE DURATION OF BREAKS



E. Subjectively Perceived Workload

Table 2 shows the average subjectively perceived workload of participants depending on the duration of break and age group. It is noticeable that the average subjectively perceived workload of participants in AG I increases with rising duration of breaks whereas the subjectively perceived workloads of participants in AG II decreases with rising duration of break. The statistical analysis however proves no significant differences.

TABLE 2
PARTICIPANTS' SUBJECTIVELY PERCEIVED WORKLOAD (GIVEN AS MEAN AND STANDARD DEVIATION)

	AG I	AG II
2 minutes	7.43 (± 1.335)	8.19 (± 2.284)
4 minutes	7.53 (± 2.466)	8.11 (± 1.225)
8 minutes	8.09 (± 1.757)	7.73 (± 1.701)
16 minutes	8.24 (± 1.655)	6.72 (± 2.601)

no workload 0…15 max. workload

CONCLUSION AND OUTLOOK

In this study, it was shown that the variation of the duration of breaks between 2 and 16 minutes does not lead to any significant performance changes. Rather, execution times are influenced by participants' age. Thus, as in the two previous studies, a significant difference between the execution times of younger and older participants was found. This difference seems descriptively to increase with the duration of the conducted breaks. Thus it can be derived from both economic and human point of view that short breaks of 2 minutes are preferable in this application. However, in terms of an age-appropriate work design, older working persons should receive more time to learn a new sensorimotor work task than younger workers. Based on the number of errors, it was shown that the product quality is not influenced by the age.

In further research the examination of the implementation of age-appropriate work designs in learning situations of manual assembly will be continued. Furthermore, a mathematical method to forecast the learning time of sensorimotor skills will be developed in order to face the challenges of the demographic change on the basis of the three conducted studies. Since the direction of change of the subjectively perceived workload in dependence of the duration of breaks was surprising, we will conduct comparable studies including measurements of objective workload, e.g. muscular fatigue.

ACKNOWLEDGMENT

This research was elaborated in the research project "Coping with Aging in Manual Assembly Systems: Age-differentiated Analyses and Mathematical Modeling for Predicting the Time Structure of Sensorimotor-skill Acquisition for Assembly in Series Production with Numerous Product Variants" (SCHL 1805/9-1), which is funded by Deutsche Forschungsgemeinschaft.

REFERENCES

Field, A. (2009). *Discovering Statistics Using SPSS* (3.ed.). London: Sage.

Fleishman, E. A. (1972). Structure and measurement of psychomotor abilities. *The psychomotor domain*, 78–196.

Fleishman, E. A., & Ellison, G. D. (1962). A factor analysis of fine manipulative performance. *Journal of Applied Psychology*, 46(2), 96–105.

Globerson, S., Levin, N., & Shtub, A. (1989). The Impact of Breaks on Forgetting When Performing A Repetitive Task. *IIE Transactions, 21*(4), 376–381. https://doi.org/10.1080/07408178908966244

Görlich, Y., & Schuler, H. (2007). *Arbeitsprobe zur berufsbezogenen Intelligenz: Technische und handwerkliche Tätigkeiten ; AZUBI-TH*. Göttingen, Wien u.a.: Hogrefe.

Greiff, M. de. (2001). Die Prognose von Lernkurven in der manuellen Montage unter besonderer Berücksichtigung der Lernkurven von Grundbewegungen. In Verein Deutscher Ingenieure (Ed.), *Fortschritt-Berichte VDI* (pp. 19–27). Düsseldorf: VDI-Verl.

Griefahn, B., Künemund, C., Bröde, P., & Mehnert, P. (2001). Zur Validität der deutschen Übersetzung des Morningness-Eveningness-Questionnaires von Horne und Östberg. *Somnologie*, 5, 71–80.

Hacker, W., & Skell, W. (1993). *Lernen in der Arbeit*. Berlin: Bundesinst. für Berufsbildung.

Hart, Sandra G., Staveland, Lowell E. (1988). Development of NASA-TLX (Task Load Index): Results of Empirical and Theoretical Research. In P. A. Hancock & N. Meshkati (Eds.), Advances in psychology: Vol. 52. *Human mental workload* (pp. 239–250). Amsterdam: North-Holland.

Iskander, A. (1968). *Über den Einfluß von Pausen auf das Anlernen sensumotorischer Fertigkeiten*(Vol. 6). Berlin/Köln/Frankfurt: Beuth.

Jeske, T. (2013). Entwicklung einer Methode zur Prognose der Anlernzeit sensumotorischer Tätigkeiten (Dissertation). Rheinisch-Westfälische Technische Hochschule Aachen, Aachen.

Kuhlenbäumer, F., Przybysz, P., & Mütze-Niewöhner, S. (2018). Age-Differentiated Analysis of the Influence of Introduction Methods on Learning Sensorimotor Tasks. In S. Trzcieliński (Ed.), *Advances in Ergonomics of Manufacturing: Managing the Enterprise of the Future: Proceedings of the AHFE 2017 International Conference on Human Aspects of Advanced Manufacturing*. Springer Verlag.

Kuhlenbäumer, F., Przybysz, P., Mütze-Niewöhner, S., & Schlick, C. M. (2017). Age-Differentiated Analysis of the Influence of Task Descriptions on Learning Sensorimotor Tasks. In C. M. Schlick, S. Duckwitz, F. Flemisch, M. Frenz, S. Kuz, A. Mertens, & S. Mütze-Niewöhner (Eds.), *Advances in Ergonomic Design of Systems, Products and Processes: Proceedings of the Annual Meeting of GfA 2016* (pp. 159–175). Berlin, Heidelberg: Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-662-53305-5_12

Neuwirth, W., & Benesch, M. (2004). *Motorische Leistungsserie: Version 24.00*. Mödling.

Rohmert, W., Ulich, E., & Rutenfranz, J. (1974). Das Anlernen sensumotorischer Fertigkeiten (2. Aufl.).*Wirtschaftliche und soziale Aspekte des technischen Wandels in der Bundesrepublik Deutschland: Forschungsprojekt des Rationalisierungs-Kuratoriums der Deutschen Wirtschaft (RKW) e.V ; Bd. 7*. Frankfurt am Main: Europ. Verl.-Anst.

Schlick, C. M., Bruder, R., & Luczak, H. (2010). *Arbeitswissenschaft* (3., vollst. überarb. und erw. Aufl). Berlin Heidelberg: Springer. Retrieved from http://dx.doi.org/10.1007/978-3-540-78333-6

Schoppe, K.-J. (1974). Das MLS-Gerät: ein neuer Testapparat zur Messung feinmotorischer Leistungen. *Diagnostica*, 20, 43–47.

Stark-Inbar, A., Raza, M., Taylor, J. A., & Ivry, R. B. (2017). Individual differences in implicit motor learning: Task specificity in sensorimotor adaptation and sequence learning. *Journal of neurophysiology*, 117(1), 412–428. https://doi.org/10.1152/jn.01141.2015