Human Behavior in the Context of Continuous Change – An Exploratory Analysis in a Research and Application Center Industry 4.0

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Abstract

The modern world of work is characterized by discontinuity and innovation. Organizations must adapt to continuous change, which makes it crucial to manage organizational knowledge. Learning and forgetting processes are necessary to react successfully to the changes. On the individual level, this means that individuals have to adapt their behavior, which is often well-learned and routinized. This study aims to take a first step toward a more detailed understanding of human behavior in the context of continuous change. For this purpose, an exploratory analysis was conducted on data collected in a Research and Application Center Industry 4.0. The participants had to deal with the continuous change of routine actions in a simulated production environment, which enabled us to measure their adaptation errors. The occurrence of adaptation errors, their dependency on the type of change, and the behavioral patterns are discussed in detail. Implications for further research are derived.

Keywords: Continuous Change, Adaptation, Type of Change, Time Course, Behavioral Patterns

1. Introduction

The management of organizational knowledge has increasingly become more important as the demand for change continuously rises (Mariano et al., 2020). New technologies, shorter product lifecycles, and rapid market changes require agile and flexible organizations that adapt to the environmental circumstances (Zhang & Cao, 2002). Nowadays workplaces are characterized by discontinuity and innovation, both of which emphasize the ever greater value of responsiveness to the environment (O'Neill & Sohal, 1999). Organizations must react to environmental changes and develop themselves continuously.

The management of transformation and change and the management of organizational knowledge are strongly intertwined (Martin de Holan & Phillips, 2004). Organizations that aim to be agile and competitive must keep their organizational memory up to date (Casey & Olivera, 2011). This means that newly relevant knowledge should be learned and anchored in memory, whereas obsolete irrelevant knowledge should be forgotten (Kluge & Gronau, 2018). The adaptation of previously learned knowledge is crucial to avoid the persistence of obsolete behavior. This increases the competitiveness of an organization and prohibits the occurrence of dysfunctional outcomes (Easterby-Smith & Lyles, 2011; Martin de Holan et al., 2004). The volitional loss of organizational knowledge is as important as organizational learning (Klammer & Gueldenberg, 2019; Mariano et al., 2020).

To reach the goal of organizational forgetting, it is crucial that adaptation and forgetting occur on the individual level (Kluge & Gronau, 2018). Individual forgetting is a precondition for organizational forgetting (Akhshik, 2014; Cegarra-Navarro & Moya, 2005), and similar to every human behavior, its success depends on various dispositional and situational factors (Niessen et al., 2020). For example, past research has shown that cognitive abilities are of particular importance for adaptation (e.g., Haase et al., 2020; Jundt et al., 2015). Situational factors, such as the environmental characteristics of a change situation, also have an impact on adaptive performance (Niessen et al., 2020).

The frequency with which changes occur in an organization is also a relevant factor that impacts individual reactions to a change (Rafferty & Griffin, 2006). Given the increasing demand for flexibility and adaptation (Mariano et al., 2020), more research is

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needed to understand human behavior in the context of continuous change. It is of interest for every organization to gain further knowledge about adaptation processes, with the goal of developing strategies for how individuals can be best supported during a change. Individuals are forced to continuously adapt their behavior to a changing environment (Zhang & Cao, 2002), and it is in the interest of every organization to reduce adaptation errors and facilitate adaptation (e.g., with purposeful work design and facilitating circumstances at work). With the aim of extending research in this field and deriving practical implications for organizations, the present study is a first starting point to investigate in detail human behavior during continuous change. Distinct from past research that often focused on radical and infrequent change events (e.g., Schüffler et al., 2020), the present study concentrates on the adaptive performance of individuals who are exposed step-by-step to changes.

2. Theoretical Background

2.1. Adaptation of knowledge during continuous change

In the world of work, change is a continuous phenomenon rather than an infrequent event (Weick & Quinn, 1999). Fast developments require constant reactions to the environmental circumstances and frequent adaptation (O'Neill & Sohal, 1999). Organizations can be regarded as self-organizing systems that interact with their environment (Weick & Quinn, 1999). Frequent adaptation and gradual learning and unlearning processes are the result (Tsang & Zahra, 2008).

On the individual level, the occurrence of continuous change requires the constant adaptation of knowledge (Tsang & Zahra, 2008). Individuals must concentrate steadily on updating their knowledge and focusing on the currently relevant. They have to learn new behavior and forget obsolete behavior to cope successfully with the changes (Schüffler et al., 2020). Only behavior that fits the currently relevant processes should be recalled from memory (Ellwart & Kluge, 2019).

When the adaptation of behavior is required, this means that specific memory items should not be recalled any longer. According to retrieval theories, the recall of memory items can be affected by retrieval cues (Roediger et al., 2010). When a memory item is associated with a specific cue, the perception of this retrieval cue triggers the recall of the associated memory item (Nairne & Pandeirada, 2008). In turn, the elimination of the associated retrieval cue can support the forgetting of a memory item and the non-occurrence of recall (Kluge & Gronau, 2018). The implementation of new retrieval cues facilitates the recall of the new, changed behavior.

When individuals are continuously exposed to changes, the question arises whether they get used to adaptation. Since past research has shown that actions themselves can also function as retrieval cues (Schüffler et al., 2019), the newly introduced changes may also function as retrieval cues for the other, past introduced changes. This would mean that continuous change supports the adaptability and helps individuals detach from old and irrelevant behavior. As the number of repetitions has an impact on the shown behavior (Pentland & Hærem, 2015), the adaptation to continuous change should be investigated over time to gain a closer understanding of the underlying processes.

2.2. Routines as a storage of knowledge

In organizations, routines are an important storage of organizational knowledge and are considered as repositories for the specific knowledge of an organization (Becker, 2004). Organizational routines are defined as "multi-actor, interlocking, reciprocally-triggered sequences of actions" (Cohen & Bacdayan, 1994, p. 554). This implies that organizational routines have to change when the organization's knowledge must be adapted (Kluge & Schilling, 2003). Old routines must be unlearned and replaced to focus on the newly relevant behavior (Tsang & Zahra, 2008).

On the individual level, the adaptation of routines means that frequently repeated and very well-learned actions become obsolete (Schüffler et al., 2020). The workers must change their behavior and learn new actions. To achieve successful change in an organization, the newly acquired knowledge needs to become visible through the workers' behavior (Miller, 1996). It is necessary that the obsolete routine actions are not executed further (Fiol & O'Connor, 2017). In addition to a change in cognition, a change in behavior is also an indicator of learning (Argote, 2011; Easterby-Smith et al., 2000). Therefore, the execution of the correct behavior shows that learning occurred successfully, whereas the execution of obsolete behavior is an indicator of unsuccessful forgetting.

Whether adaptation is successful or not might depend on the type of change and the behavior that should be changed. For example, Schüffler et al. (2020) showed that the adaptation of well-learned actions is especially difficult. In general, organizational change might require different types of behavior changes on the individual level. Depending on situational characteristics, it could happen that actions should be executed in a different manner than before or be completely omitted. In addition, it could occur that new

actions suddenly have to be added. When adaptation fails, it might have dramatic consequences for the individual and the organization, such as regarding safety or working time. For example, in high-reliability organizations, such as airlines in the aviation sector, the false execution of an action might have catastrophic consequences (Sieberichs & Kluge, 2021).

Apart from the difficulties a change of a routine action might cause, the routine itself can also be a source of continuous change (Feldman, 2000). When individuals reflect on their actions and react to the outcomes of their previous routine execution, a change in behavior might be the result. There is an internal dynamic that might lead to continuous improvements (Feldman, 2000). In the fast-changing world of work, continuously improving behavior and adapting the knowledge to environmental changes are indispensable (Mariano et al., 2020). The adaptation of routines is crucial for an agile and future-oriented organization.

2.3. Purpose of the study

The purpose of this study is to investigate human behavior in the context of continuous change. Based on the theoretical background outlined above, the following research gaps were identified, and three research questions were derived.

First, more research about the adaptive performance of individuals and the success of adaptation is necessary. A closer understanding of humans' ability to adapt to continuously introduced changes would provide interesting knowledge for organizations. For this purpose, the following research question was derived:

(1) *How many adaptation errors are made when participants must adapt to continuously introduced changes?*

Second, whether the type of change has an impact on the success of adaptation remains unclear. The type of change might differ depending on the change situation. To gain more knowledge about the underlying mechanisms, the following research question was derived:

(2) *Is there a difference in the number of adaptation errors whether an action should be executed in a changed manner, should be completely omitted, or is newly introduced?*

Third, continuous change is characterized by changes that are introduced in a successive manner. Since routines play an essential role in organizations, the execution of routine actions and the reaction to routine changes should be investigated over time. For this purpose, the following research question was derived:

(3) *Are there specific behavioral patterns that can be observed when participants must adapt to continuously introduced changes?*

3. Methodology

The present analysis involves an in-depth analysis of previously collected data. Human behavior during continuous change was investigated as a first starting point to extend the research in this field. For this purpose, the data of an experimental study were used. The study was conducted within the project "Cyber-physical forgetting in socio-digital systems" (funded by the German Research Foundation (Deutsche Forschungsgemeinschaft, DFG), project number: 317987159, grant numbers KL 2207/6-2 & GR 1846/21-2), with the aim to investigate the adaptation and intentional forgetting of routine actions during episodic or continuous change (single-factor design). The study was approved by the Ethics Committee of the Faculty of Psychology at Ruhr University Bochum (No. 243). For the present analysis, only the data with participants who had to face continuous change were considered. The data of 18 participants who were faced with continuous change were collected between September 2021 and December 2021. These participants were recruited via social media platforms and flyers handed out on campus at Ruhr University Bochum. Psychology and business psychology students were not allowed to participate as they might know the purpose of the study. Most of the participants were students from other faculties.

3.1. The Research and Application Center Industry 4.0

The data collection occurred in the Research and Application Center Industry 4.0 (RACI) at Ruhr University Bochum. The RACI is a special-purpose setting because it is a laboratory that is equipped as a production setting (Kluge et al., 2019; Stone-Romero, 2011). This has the advantage that experiments can be conducted in a controlled laboratory setting with a close-to-real environment (Kluge et al., 2019). In the present study, the production of artificial knee joints was simulated in the RACI with the help of various hardware and software components (Figure 1; Lass & Gronau, 2020). There were two work positions where participants could interact with the machines and workpieces to start and monitor the corresponding production process. The first work position focused on milling and grinding the workpieces, while the second work position focused on lasering and polishing them. The machines were represented by big cubes with a

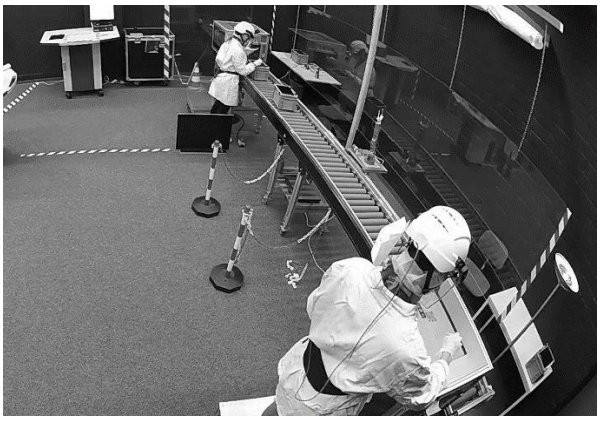

Figure 1. The Research and Application Center Industry 4.0 at Ruhr University Bochum

computer interface, and the workpieces were simulated by small cubes with tablets. Audible and visual effects as well as the movement of physical components (e.g., a robotic arm) enhanced the participants' experience in the production setting.

3.2. Procedure

The research design contained two measurement points in the RACI. At the first measurement point (t1), the participants came to the RACI in groups of two to learn and train in the initial production routine. The two group members were randomly assigned to one of the work positions. Standardized video material introduced them to the setting and the subsequent tasks. The participants were told that they must process artificial knee joints to research the learnability of a production process in cooperation with a fictitious company. Then, the participants received printed learning material that explained the production steps on their individual work position. Although the participants performed a sequential group task, the production tasks on each work position did not depend on the production tasks of the other group member. The participants produced three workpieces with the help of the learning material. After this, the learning material was removed, and the participants had to produce a further nine workpieces. In some cases, the participants needed too much time to complete the production of all nine workpieces, which is the reason for fewer observations in some cases. At the end of each workpiece processing per work position, the participants received feedback on the quality of the processed workpiece (good or bad). The routine actions were not equally important to receive a workpiece with high quality because some of the actions were relevant for another reason (e.g., for safety). At the beginning and end of the first measurement point, the participants had to fill out several questionnaires that measured, for example, specific self-efficacy (Schwarzer & Jerusalem, 1999) or presence (Frank, 2015). They were then sent home with the instruction to further practice their individual production steps with the use of an online training program. They had to train in their specific routine for at least 10 minutes per day to consolidate the acquired knowledge about the production process.

One week after the first measurement point, the participants returned to the RACI (t2). They thought that they again must perform their previously learned routine. The participants were instructed to produce one workpiece with the production steps they have learned and trained. Then they were interrupted and told that the company had an important message for them. Half of the groups were informed that the machines received a software update that caused a change in the specific production steps. All these changes were introduced during the production process of the subsequent workpiece and had to be realized for all the following workpieces (episodic change). The other half of the groups (these were the focus in the present study) were told that a new technology enables the machines to continuously improve the production process. This means that changes of specific production steps occurred stepwise during multiple production processes (continuous change). After the introduction of a changing production step, the changed action had to be realized for all the following production processes. When all the changes were introduced, a further six workpieces had to be processed with the new production steps (Figure 2). Again, some participants needed so much time to process the workpieces that not all the workpieces could be completed. The participants again received feedback on the quality of the processed workpiece (good or bad) at the end of every workpiece processing per work position.

At the beginning (after the participants had received the message that changes would occur) and end of the second measurement point, the participants again had to fill out several questionnaires that measured, for example, presence (Frank, 2015) or retentivity (WIT-2; Kersting et al., 2008). After the debriefing, the participants received their financial reward for participation.

3.3. Implementation of continuous change

In the experimental study, the type of change (episodic versus continuous change) was the independent variable. As the present study focuses on continuous change, only this condition will be described in detail in this paper.

At the second measurement point, the changes were introduced with the help of instruction texts that were

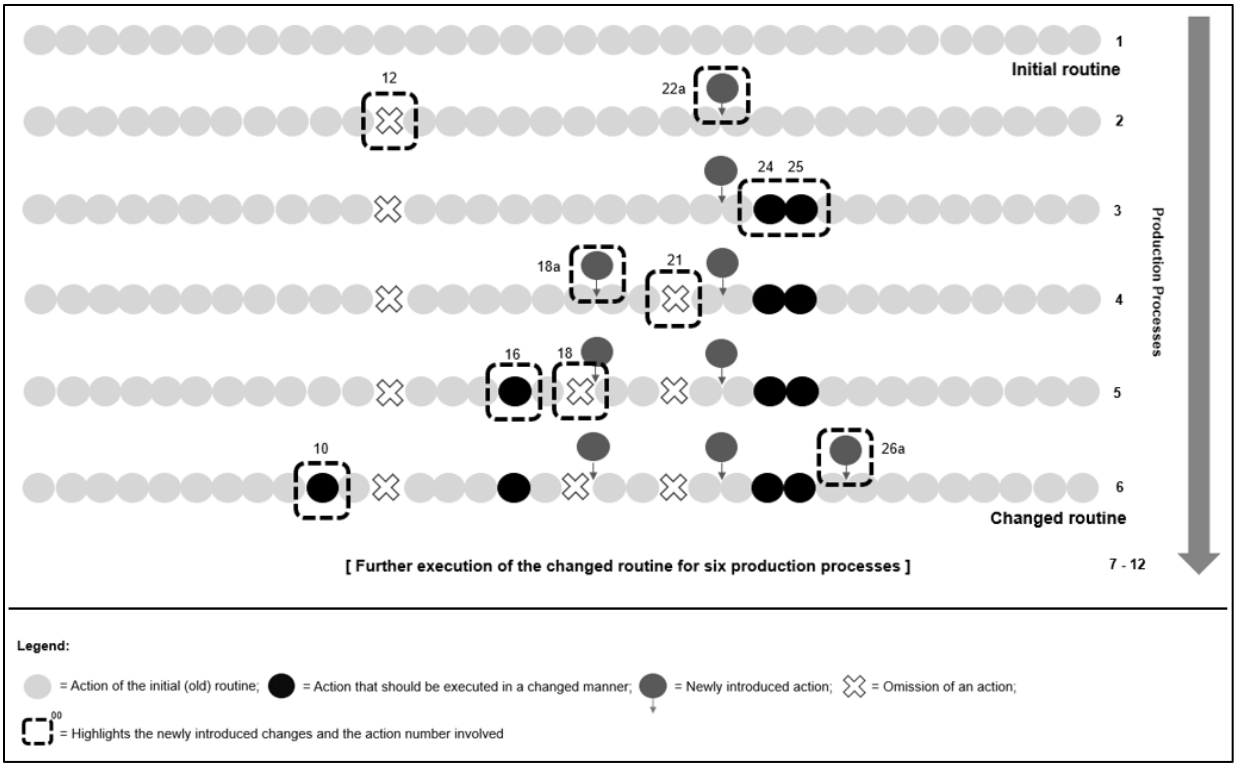

Figure 2. Implementation of continuous change at the second measurement point

presented on the digital work plan. In general, the participants received all the necessary information for processing the workpieces from the digital work plan, such as the program for grinding/polishing. They had to navigate through the work plan to receive all the information needed. To introduce the changes, new instruction texts appeared when a predefined button is pushed on the work plan. The position and content of the instruction texts varied depending on the number of the production process. Although the two work positions differed in the routine actions they had to execute, they were designed to be as equivalent as possible. The positions and types of changes were equal for the two work positions. The changes included the following three general types:

(1) Actions that had been learned at t1 should be executed in a changed manner (e.g., measure the workpiece in inches instead of centimeters). In Figure 2, these changes are visualized through a black color in contrast to a light gray color of old routine actions.

(2) Actions that had been learned at t1 should be omitted (e.g., to not enable the machine/robot). In Figure 2, these changes are visualized through a cross at the position of the omitted action.

(3) Actions that should not have been executed at t1 were newly introduced (e.g., calibrate the machine/robot). In Figure 2, these changes are visualized through a medium gray color and an arrow.

Referring to this change systematization, ten changes were introduced at the second measurement point in the RACI. These are visualized in Figure 2. During the second production process, for example, the omission of the 12th action was introduced. Action 22a was added and newly introduced ("a" indicates that the action was introduced between the 22nd and 23rd actions of the initial routine). In general, the changes were split over the course of five production processes (two changes per production process) to depict continuous changes. Further information about the changes is provided in Figure 3.

3.4. Dependent variable

The dependent variable refers to the success of the performance adaptation that we operationalized through the adaptation errors that were made. Every click the participants made on the tablets and machines was

		Work position 1		Work position 2	
	Action Number	Instruction t1	Instruction t2	Instruction t1	Instruction t2
Actions that should be executed in a changed manner	24	Choose program from configuration *no. 1* for grinding	Choose program from configuration *no. 2* for grinding	Choose program from configuration *no. 1* for polishing	Choose program from configuration *no. 2* for polishing
	25	Choose duration from configuration *no. 1* for grinding	Choose duration from configuration *no. 2* for grinding	Choose speed from configuration *no. 1* for polishing	Choose speed from configuration *no. 2* for polishing
	16	Measure the workpiece in *cm*	Measure the workpiece in *inches*	Enter the *order number* for generating the QR code	Enter the *part number* for generating the QR code
	10	Check *all the pieces* of the machine	Check *only the pieces displayed on the work plan*	Check *all the pieces* of the robot	Check *only the pieces displayed on the work plan*
Actions that should be omitted	12	Enable the machine	-	Enable the robot	-
	21	Enter the duration for milling	-	Enter the speed for lasering	-
	18	Fix the workpiece	-	Transmit the QR code	-
Actions that are newly introduced	22a	-	Clean the machine	-	Realign the robot
	18a	-	Calibrate the machine	-	Calibrate the robot
	26a	-	Click "Finish"	-	Click "Finish"

Figure 3. Overview of the changes

recorded. This enabled us to categorize the executed behavior whether it was correct or false. Additionally, the participants were equipped with mobile cameras that recorded their behavior. We counted an adaptation error in the following cases:

(1) An action that should be executed in a changed manner was still executed like at t1 (e.g., the workpiece was still measured in centimeters although the unit had changed to inches)

(2) An action that should be omitted was further executed (e.g., the machine/robot was still enabled)

(3) An action that was newly introduced was omitted (e.g., the machine/robot was not calibrated although this was newly required)

4. Exploratory Analysis

Owing to technical problems, the data from two participants had to be excluded from analysis. In total, the data from 16 participants were analyzed (8 worked on work position 1, 8 worked on work position 2; age: $M = 25.75$, $SD = 4.28$; 7 male, 9 female). To answer our research questions, we focused on the analysis of six specific production processes: the five workpieces during which the changes were introduced and their subsequent workpiece (production processes number two to seven). The number of adaptation errors made during the processing of these workpieces was considered.

4.1. Analysis of the adaptation errors

To answer our first research question, we analyzed how many adaptation errors were made in general. Without considering the different types of changes and positions of introduction, one out of eight participants on work position 1 (12.5 %) and four out of eight participants on work position 2 (50.0 %) made at least one adaptation error during the six production processes that were analyzed. This result indicates that most of the participants were well able to deal with the continuously introduced changes.

To answer our second research question, we analyzed whether it makes a difference if the action should be executed in a changed manner, should be completely omitted, or was newly introduced. In our analyzed data set, none of the participants made an adaptation error when executing an action that should be executed in a changed manner. All the participants were well able to adapt the manner of execution. Regarding the actions that should be completely omitted, one out of eight participants on work position 1 (12.5 %) and

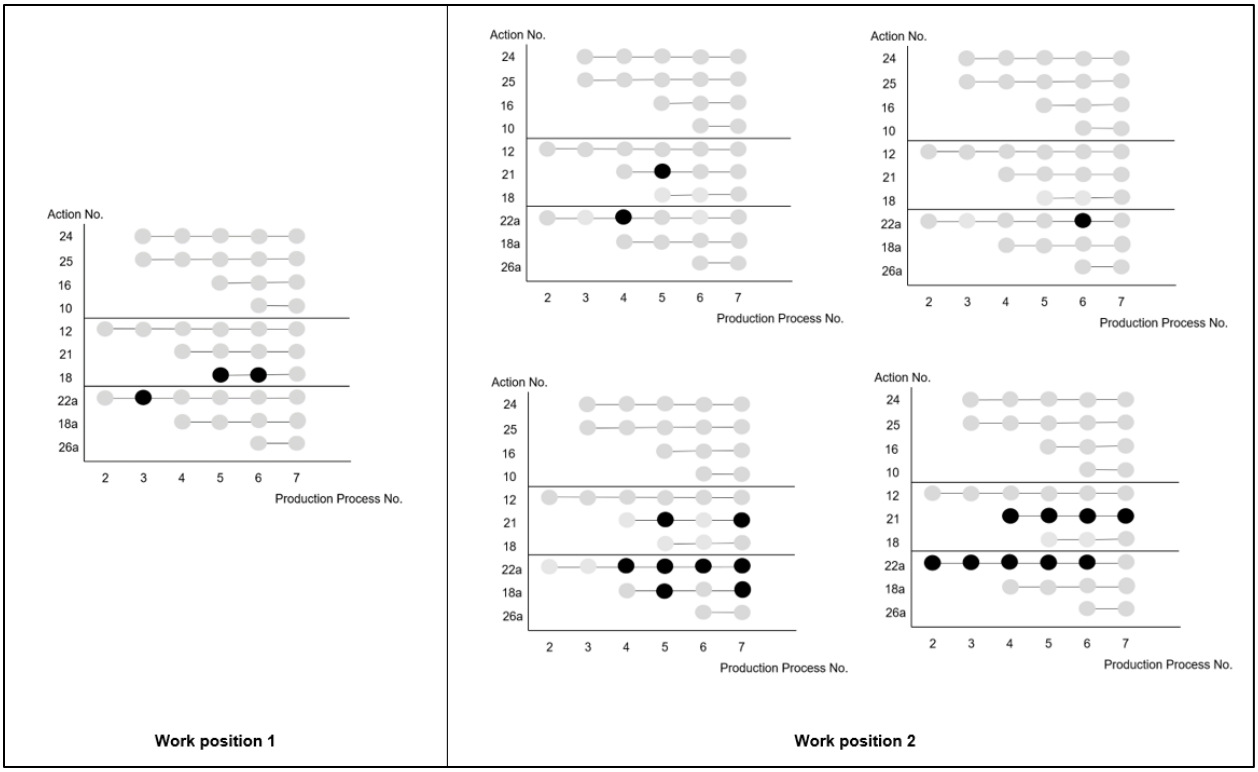

Figure 4. Behavioral patterns over time for participants who made at least one adaptation error
(black: adaptation error; light gray: no adaptation error)

three out of eight participants on work position 2 (37.5 %) made at least one adaptation error. Regarding newly introduced actions, one out of eight participants on work position 1 (12.5 %) and four out of eight participants on work position 2 (50.0 %) made at least one adaptation error. It must be considered that the possible number of adaptation errors was not equal for all the different actions owing to the stepwise introduction of the changes. For example, when the omission of a specific action was introduced during one of the first production processes we analyzed, many adaptation errors could be made for this specific action since there were many subsequent iterations. When the omission of a specific action was introduced during one of the last production processes we analyzed, less adaptation errors could be made for this specific action since there were only a few subsequent iterations. Nevertheless, it seems that most of the adaptation errors occurred related to the newly introduced actions or actions that should be omitted.

4.2. Analysis of behavioral patterns over time

To answer our third research question, we analyzed whether the participants made single or multiple adaptation errors. For this purpose, only the participants who made at least one adaptation error were considered. The courses over the six production processes that were analyzed are displayed in Figure 4. Each picture shows the performance of one participant. The colored circles indicate whether the participants made an adaptation error or not (black: adaptation error; light gray: no adaptation error). The results show that most of the participants made multiple adaptation errors. The majority even made the same adaptation error more than once, sometimes even one after the other. This outcome indicates that some changes seem to be more difficult than others.

5. Discussion

The purpose of this study was to investigate human behavior in the context of continuous change. Our exploratory analysis outlined that the participants in the RACI were generally well able to deal with the continuously introduced changes, indicating that adaptation to continuous change succeeded well in our sample. Most of the participants did not make any adaptation error (research question 1). This finding fits the assumption that the occurrence of subsequent changes might function as a retrieval cue for the previously introduced changes. According to the results

of Schüffler et al. (2019), routine actions can also be retrieval cues that trigger the execution of subsequent actions. The continuous occurrence of changes might help make all the previous changes salient and could be an explanation for the small number of adaptation errors. The participants seemed to be able to deal with changes that were introduced in a stepwise manner. In most of the cases, these continuous changes did not seem to exceed their cognitive capacity.

In cases where adaptation errors were made, the execution of newly introduced actions and the omission of obsolete actions appeared particularly difficult. There was no problem adapting the way in which an action should be executed. In contrast to this, our findings indicate that it was not that easy to adapt the execution or non-execution of an action. In our sample, the type of change seemed to make a difference for the success of adaptation (research question 2). Again, the composition of retrieval cues might be an explanation for these differences. In addition to the information required for the unchanged execution of actions, the participants also had all the information required for the execution in a changed manner on their digital work plan. The perception of this information is a strong retrieval cue for the change, which might have facilitated the adaptation. For the execution of newly introduced actions and non-execution of obsolete actions, the cues that point out the changes might not be that salient. Past research has outlined that the composition of retrieval cues has an impact on forgetting and adaptation (Kluge & Gronau, 2018). Regarding the omission of obsolete actions, it might also be the case that participants tended to push one button too much rather than too less, which might also be an explanation for the adaptation errors.

The data likewise showed that the participants who made an adaptation error made multiple adaptation errors in most of the cases. Sometimes the adaptation errors directly followed each other. This finding indicates that adaptation errors often are not an exception or a careless mistake and outlines the occurrence of specific behavioral patterns (research question 3). Some specific changes seemed to be particularly difficult for the participants. They made relapse errors to previously learned routine actions and did not adapt their behavior according to the current requirements.

5.1. Limitations

The present analysis has certain limitations that must be considered. First, the small sample size and descriptive approach of the analysis must be mentioned as these lead to a limited generalizability of our results. Second, we must consider that we did not control whether the participants correctly understood the texts that introduced the changes. Of course, this is also dependent on how well the participants had learned the previous routine. In this context, it must be considered that some participants already executed specific actions of the new routine even though the changes had not yet been introduced. Then, the changes did not function as real changes for the participants. For example, some participants already omitted an action even though the omission of this action was not yet introduced and required. Later, the omission of this action did not function as a change for those participants because they accidentally have already omitted it before. Therefore, the pre-change performance can have an impact on the number of adaptation errors. Nevertheless, with our first descriptive analysis we focused on the adaptation errors that were made and did not incorporate correctly executed changes and possible reasons for those in our analysis. Therefore, we did not consider the pre-change performance of the participants. Additionally, it must be considered that the changes occurred for different types of actions with different contents. A closer look on the quality and plausibility of the actions and their position and relevance for the whole production process is necessary, as these aspects might have an impact on the success of adaptation and possible learning from adaptation errors. Those limitations concerning the research design must be considered. In this context, it is also necessary to check whether the performance of participants on work position 1 systematically differs from the performance of participants on work position 2. Technical problems and interruptions during the laboratory sessions might have affected the behavior of the participants as well.

5.2. Implications

Even when certain limitations must be considered, the results of the present analysis can be taken as a first starting point for further research. Our results indicate that the type of change is relevant to the success of adaptation. Future work should extend the research in this field to provide an explanation for this distinction. As it seems to be easier to execute an action in a changed manner than to completely omit it, it can be derived that substituting obsolete actions might be more helpful instead of requiring their omission. This approach might help make the change more salient with the goal to facilitate adaptation. In addition, our results underline the importance of a purposeful work design. The composition and salience of retrieval cues seem to have an impact on the success of adaptation. This finding can be used to facilitate adaptation through the implementation and elimination of retrieval cues in the work environment.

Additionally, our results indicate that, in most of the cases, multiple adaptation errors were made and that sometimes even the same errors were made in a row. The participants seemed to commit relapse errors, which underlines how demanding it is to adapt routinized actions. Past research has already shown that environmental circumstances can have an impact on the number of relapse errors. For example, Betsch et al. (2004) showed that time pressure has a negative impact on adaptation. Further research should investigate factors that hinder or facilitate adaptation, particularly during continuous change. Based on this, work and work environments should be designed to facilitate the adaptation of old and well-learned routine actions.

6. Conclusion

To sum up, the study presented can be seen as a first step toward a more detailed understanding about human behavior in the context of continuous change. Our research questions on human behavior in the context of continuous change were answered through the analysis of data collected in a simulated and close-to-real production environment. The results underline the need for further research in this field and provide concrete starting points where future work can connect. In general, the present analysis indicates that most of the participants were well able to adapt to continuously introduced changes. Nevertheless, it seems that the type of change is relevant to the success of adaptation, which would have meaningful implications for the management of change processes. Adaptation seems to be particularly difficult when the omission of a previously learned action or execution of a newly introduced action is required. The participants who showed an adaptation error often made multiple adaptation errors, which underlines how difficult it is to forget routine actions. Further research should investigate the adaptation to continuous change in detail to derive concrete implications for a purposeful design of change processes.

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