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Implications for behavioral inhibition and activation in evacuation scenarios: Applied human factors analysis

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Abstract

In the case of evacuation events, human factors play an important role for the effective outcome of evacuations. Therefore, the design and organization of evacuation systems can be seen as crucial factor. Behavioral aspects of human beings in critical situations can be described considering the theory of behavioral inhibition and activation. Furthermore, the behavior of evacuation assistants may have a decisive role on evacuees' behavior. In an experimental study it was investigated, how the appearance of an evacuation assistant influences the behavior and the emotional state of evacuees while acting in different conflict situations. A multi-dimensional approach was chosen to combine assessments of the subjective emotional state and objective psychophysiological responses of the study participants. Different conflict situations were assessed with 23 untrained volunteers. The results of the psychophysiological responses and the subjective assessments of the participants indicate a stronger activation of the behavioral inhibition system (BIS) under dangerous situation without an evacuation assistant than with an evacuation assistant. If a departing from the group of evacuees was required due to tasks, stronger activation of the behavioral activation system (BAS) was shown by persons who evacuated without evacuation assistant. Regarding the behavior of the evacuation assistant, the results strongly advise against the assignment of evacuation assistants that show unsafe occurrence and unsafe actions during the evacuation. Overall, the results give important indications to improve evacuation situations by avoiding critical situations in which persons tend to become unconfident and therefore become incapable of action.

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Keywords: Evacuation; Human factors; Behavioral inhibition; Behavioral activation; Experimental study; Psychophysiological activation

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1. Introduction

In the case of evacuation events (e.g. fire, natural disaster, terrorist attacks, etc.), human factors play an important role for the effective outcome of evacuations. Therefore, the design and organization of evacuation systems can be seen as crucial factor to gain a positive outcome within such critical events. Different conflict situations are able to influence people in a way that they act neglecting to leave the danger zone as soon as possible. Lewin [1] defines "conflict" as "(…) a situation in which oppositely directed, simultaneously acting forces of approximately equal strength work upon the individual" (p. 122). Such situations are, for example, other individuals who are still in the danger situation, wards, important documents, expensive things, etc.

Behavioral aspects of human beings in critical situations can be described considering the theory of behavioral inhibition and activation (BIS, BAS) [2]. The theory is based on research of neurobiological processes of anxiety, whereby conflicting aspects of a situation are able to inhibit ongoing behavior of an individual (e.g. stopping, hesitant evacuation behavior, …). On the other hand the behavioral activation system (BAS) is responsible for an actively facing of difficult situations (e.g. the initial step to start with the evacuation process). Fowles [3,4] postulated the BIS to be associated with electrodermal activity and the BAS to be associated with cardiovascular activity.

Furthermore, the behavior of evacuation assistants (e.g. poise, unsafe occurrence, and unsafe actions of the evacuation assistant) may have a decisive role on evacuees' behavior. According to Allison [5] people tend to orientate on persons who are perceived as powerful, successful and with high status. The more reliable the person appears, the more information about the appropriate behavior for the specific situation is subjectively provided by this person.

In an experimental study the research question was investigated, how the appearance of an evacuation assistant influences the behavior as well as the emotional state of evacuees while acting in different conflict situations.

2. Method

2.1. Participants

In total, 23 untrained volunteers participated in the experimental study: 11 women and 12 men between 19 and 56 years old with an average age of 28.09 years (*SD* = 10.27). The 23 volunteers were randomly assigned to four groups of four to eight participants. Four participants of each group were equipped with the portable VARIOPORT system of Becker Meditec to record cardiovascular (ECG) and electrodermal (EDA) activity. One participant of each group was additionally equipped with wearable eye tracking glasses (ETG) 1.0 of SensoMotoric Instruments™ (SMI). The exact distribution among the sample regarding the different psychophysiological measures can be seen in Table 1.

Table 1. Distribution among the total sample and the partial samples.

	N	*M*	*SD*	Men / Women
Total sample	23	28.09	10.27	12/11
Partial sample EDA	13	30.08	11.86	5/8
Partial sample ECG	12	27.92	9.34	5/7
Partial sample ETG	4	28.89	12.73	2/2

2.2. Task, measures and procedure

To stay as close to reality as possible, the experimental study was investigated in a realistic environment. The participants were naïve to the research question and did not know that they have to evacuate before the fire alarm was presented. Two different conflict situations were instructed within this study and the intensity of the conflict situation was varied (low / high). For example, the exit was blocked by dense smoke in the first trial. One group of the participants were instructed in an anxiety provoking way (smoke might be harmful; high conflict situation), the

other group of participants received a non-anxiety instruction (smoke is artificial and therefore not harmful; low conflict situation). In the second trial, both groups of participants received task instructions: one task required a departing from the group (e.g. searching for other evacuees, their valuables etc.; high conflict situation), whereas the other task could be executed while remaining with the group (e.g. observation task; low conflict situation). The first trial was intended to simulate a conflict situation which should activate the behavioral inhibition system (BIS), whereas the second trial was intended to simulate a situation in which an active response was required and therefore should activate the behavioral activation system (BAS). In addition, the occurrence of the evacuation assistant was manipulated within the different trials (e.g. with/without evacuation assistant; without evacuation assistant/evacuation assistant with unsafe/poise occurrence). A multi-dimensional approach was chosen to combine assessments of the subjective emotional state as well as objective psychophysiological responses of the study participants (cardiovascular and electrodermal activity, eye tracking).

2.2.1. Psychophysiological recording

Electrodermal activity was recorded from the inner palm (thenar and hypothenar) of the non-dominant hand of the participants. Two Ag/AgCl electrodes filled with 0.5% NaCl paste, with a diameter of 22mm were attached. The recording was accomplished with 0.5 constant voltages. The amplitude-criteria was set to 0.01 μS. Overall three different parameters were assessed: Skin Conductance Level (SCL), non-specific Skin Conductance Response (NS.SCR) and sum-amplitude of NS.SCR. Cardiovascular activity was recorded using a thorax lead. Two different parameters were recorded: Heart rate (HR) in beats per minute (bpm) and heart rate variability (HRV) calculated as mean square of successive differences (RMSSD). Activation of the BAS was indexed by EKG activity; activation of the BIS was indexed by EDA activity.

2.2.2. Subjective measurements

To assess the emotional state of the participants after each trial an adjective checklist consisting of 24 items was used [6]. Additionally, a short questionnaire (10 items) to assess the subjective perception of the previous experienced situation was engaged.

2.2.3. Eye Tracking

To measure the gaze pointer for both eyes, SMI™ eye tracking glasses - a non-invasive video based binocular eye tracker with automatic parallax compensation and 30 Hz sampling rate - was used. The gaze pointer accuracy of 0.5°–1.0° and a tracking range of 80°/60° horizontal/vertical assure a precise localization of the human's gaze in the HD 1280x960 scene video with 24 fps. An accurate three point calibration was performed and the gaze positions within the HD scene video frames were used for further processing.

2.2.4. Video Recordings

To support the analysis how the evacuees act within the different situations, four light sensitive fixed network cameras (Axis) were used to monitor the participants along the escape routes (see Figure 1). The video streams were recorded time-synchronized on notebooks and a common time base with further measurements was established, so that the external measurements could be compared to the observed situation in the video.

Fig. 1. Video monitoring of the participant along the escape routes.

2.3. Statistical Analysis

The statistical analyses of the data were conducted using the software SPSS 20.0 for Windows. Analyses of variance were performed for calculating the results. The analyses were based on a significance level of 5%.

3. Results

3.1. Behavioral inhibition system (BIS)

The results of an analysis of variance showed a significant interaction conflict x evacuation assistant for one parameter of the electrodermal activity, NS.SCR, $F(1,9) = 8.85$, $p = .016$. Participants, who faced a high conflict situation without an evacuation assistant showed a significant higher frequency of non-specific spontaneous fluctuations (NS.SCR; $M = .78$, $SD = 1.13$) than participants who faced the same situation with an evacuation assistant ($M = -2.00$, $SD = 1.65$). This effect was not observable under the low conflict situation ($M_{without\ ev.assistance} = -.17$, $SD_{without\ ev.assistance} = .76$; $M_{with\ ev.assistance} = .29$, $SD_{with\ ev.assistance} = .57$; see Figure 2).

The subjective assessments showed that participants with evacuation assistant reported significant better mood, $F(1,20) = 5.15$, $p = .034$ ($M_{with\ ev.assistance} = 3.98$, $SD_{with\ ev.assistance} = .88$; $M_{without\ ev.assistance} = 2.71$, $SD_{without\ ev.assistance} = 1.76$), and tend to be more balanced, $F(1,20) = 3.35$, $p = .082$ ($M_{with\ ev.assistance} = 3.79$, $SD_{with\ ev.assistance} = 1.05$; $M_{without\ ev.assistance} = 2.81$, $SD_{without\ ev.assistance} = 1.44$) than participants that evacuated without an evacuation assistant. Furthermore, the results of the short questionnaire indicated significant less perceived “anger and frustration”, $F(1,19) = 7.05$, $p = .016$ ($M_{with\ ev.assistance} = .33$, $SD_{with\ ev.assistance} = .49$; $M_{without\ ev.assistance} = 1.75$, $SD_{without\ ev.assistance} = 1.96$), and “goal-blocking”, $F(1,19) = 4.36$, $p = .050$ ($M_{with\ ev.assistance} = 1.00$, $SD_{with\ ev.assistance} = 1.17$; $M_{without\ ev.assistance} = 2.38$, $SD_{without\ ev.assistance} = 1.90$), for participants with than for participants without evacuation assistant. All other effects did not reach the level of significance.

3.2. Behavioral activation system (BAS)

The results of an analysis of variance showed a tendency towards an interaction between conflict and evacuation assistant for heart rate (HR), $F(1,6) = 4.52$, $p = .078$. Participants, who faced a high conflict situation without an evacuation assistant showed a tendency toward a higher HR ($M = 43.51$, $SD = 18.82$) than participants who faced the same situation with an evacuation assistant ($M = 17.34$, $SD = 5.93$). This effect was not observable under the low conflict situation ($M_{without\ ev.assistance} = 13.37$, $SD_{without\ ev.assistance} = 7.16$; $M_{with\ ev.assistance} = 18.90$, $SD_{with\ ev.assistance} = 19.67$; see Figure 3).

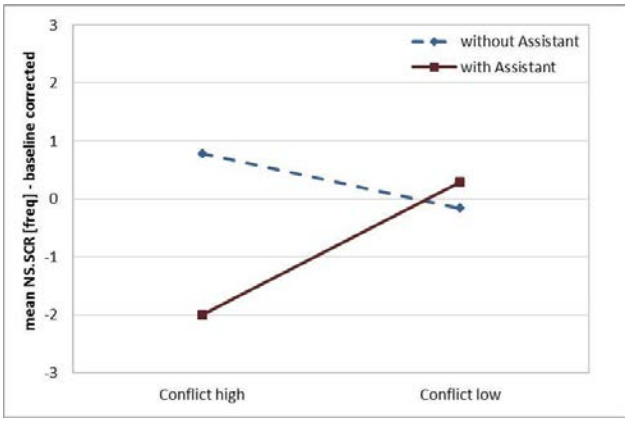

Fig. 2. Interaction conflict x evacuation assistant - mean values of NS.SCR.

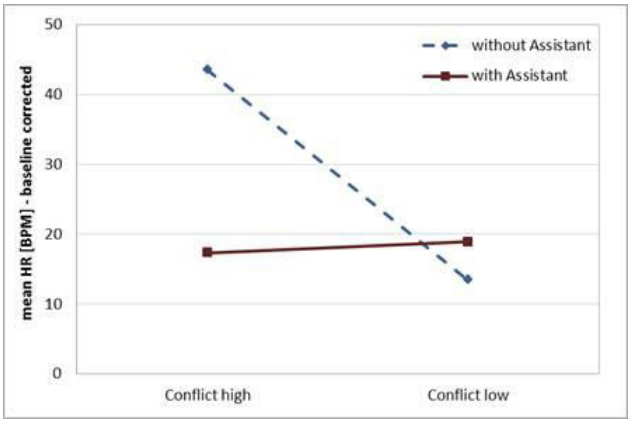

Fig. 3. Interaction conflict x evacuation assistant - mean values of heart rate (bpm).

The results of the short questionnaire showed in four scales a significant interaction conflict x evacuation assistant: “behavioral inhibition”, $F(1,18) = 6.60$, $p = .019$, “goal-blocking”, $F(2,18) = 4.86$, $p = .041$, “anxiety and uncertainty”, $F(2,18) = 6.00$, $p = .025$, as well as “anger and frustration”, $F(1,18) = 5.98$, $p = .025$. If departing from the group was required (conflict high), participants with evacuation assistant reported significant more “behavioral inhibition”, “goal-blocking”, “anxiety and uncertainty” and “anger and frustration” than participants without evacuation assistant. The mean values and standard deviations of each group are shown in Table 2. All other effects did not reach the level of significance.

Table 2. Mean values and standard deviations for the scales of the short questionnaire.

Scale	Evacuation assistance	conflict	*M*	*SD*
“behavioral inhibition”	without	low	2.00	1.73
		high	.50	.71
	with	low	.43	.61
		high	2.31	1.96
“goal-blocking”	without	low	1.67	1.76
		high	.13	.25
	with	low	.71	1.11
		high	2.56	2.27
“anxiety and uncertainty”	without	low	1.33	1.53
		high	.50	.71
	with	low	.50	.76
		high	2.31	1.46
“anger and frustration”	without	low	1.00	1.73
		high	.13	.25
	with	low	.00	.00
		high	1.44	1.35

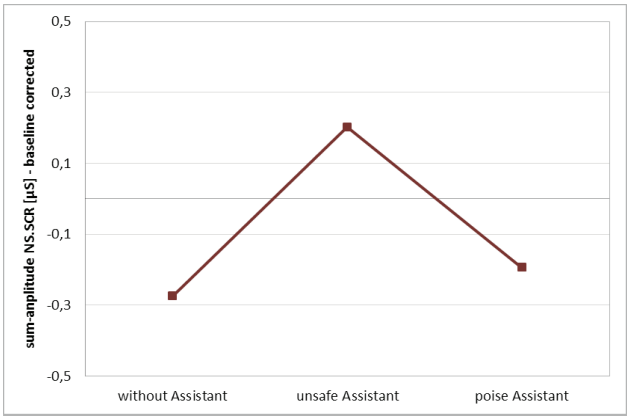

Fig. 4. Effect variation of the occurrence of the evacuation assistant – sum-amplitude of NS.SCR.

3.3. Occurrence of the evacuation assistant

Regarding the occurrence of the evacuation assistant a univariate analysis of variance indicates a tendency towards significance, $F(2,15) = 3.272$, $p = .066$. Participants who evacuated with an evacuation assistant with unsafe occurrence showed higher sum-amplitude of NS.SCR ($M = .20$, $SD = .35$) than participants who evacuated without an evacuation assistant ($M = -.28$, $SD = .39$; post-hoc test $p = .076$; see Figure 4).

3.4. Visual attention

To investigate the influence of evacuation assistance on the visual attention a fixation distribution as proposed by Paletta et al. [7] was implemented. The approach calculates the distribution of fixations for the participants, gathered by ETG data, relative to evacuation assistance relevant objects as exit signage, path markings on the floor and evacuation assistants. Analysis has shown that participants focus other persons, like evacuation assistants or other participants, while exit-signage is mostly ignored (see Figure 5).

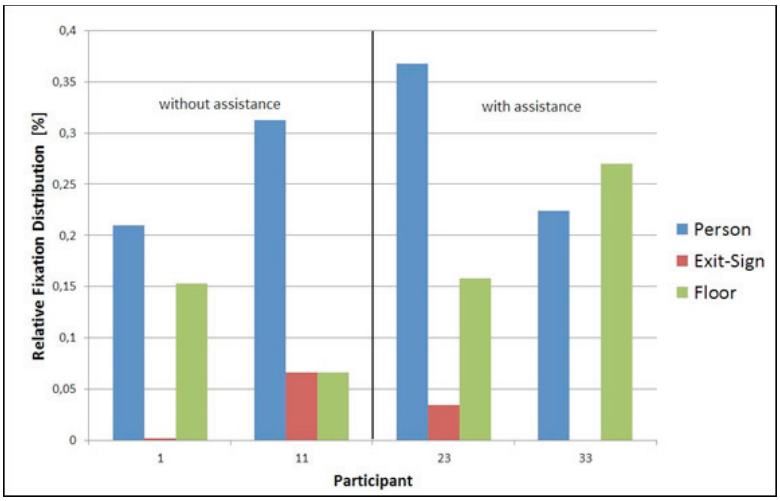

Fig. 5. Relative Fixation Distribution for the evacuation assistance objects (person, exit-sign, and floor).

4. Discussion

In this study, the research question was investigated how the appearance of an evacuation assistant influences the behavior as well as the emotional state of evacuees while acting in different conflict situations.

The results of the electrodermal activity indicate an activation of the behavioral inhibition system (BIS) if participants faced a conflict situation of high intensity without an evacuation assistant. This is in line with the research results of Fowles [3,4], who postulates an association between BIS and electrodermal activity. In addition, the subjective ratings support the results of the psychophysiological parameters. Participants with evacuation assistant reported significant better mood and tend to be more balanced than participants that evacuated without an evacuation assistant. Furthermore, the results of the short questionnaire indicated significant less perceived “anger and frustration” and “goal-blocking” for participants with than for participants without evacuation assistant. Overall, the results suggest that the occurrence of an evacuation assistant acted as a stabilizing factor and safety signal in this uncertain and ambiguous situation.

The results of the cardiovascular activity indicate a stronger activation of the behavioral activation system (BAS) if a departing from the group of evacuees was required due to tasks (e.g like searching for other evacuees, their valuables etc.) by persons who evacuated without an evacuation assistant. This is also in line with Fowles’ [3,4] research results and are confirmed by the subjective data. If departing from the group was required (conflict high), participants with evacuation assistant reported significant more “behavioral inhibition”, “goal-blocking”, “anxiety and uncertainty” and “anger and frustration” than participants without evacuation assistant. These results suggest that people with an evacuation assistant experienced less conflict in this situation than people evacuating with an evacuation assistant.

Regarding the behavior of the evacuation assistant, the results of the electrodermal activity indicate a stronger activation of the behavioral inhibition system (BIS) if participants evacuated with an evacuation assistant with unsafe occurrence than if participants evacuated without an evacuation assistant. Further studies should address the possible negative effects of an evacuation assistant with unsafe occurrence.

Analysis of Eye Tracking data shows that fixations are focused rather on social cues, such as on the appearance of persons, especially on evacuation assistants that have been introduced as authorized persons before the study. This suggests that a generalization of the outfits of evacuation assistants is highly important to make them recognized as authorized persons and from this focus the attention of the evacuees on appropriate social cues.

To sum it up, the results of this study strongly advise against the assignment of evacuation assistants that show unsafe occurrence and unsafe actions during the evacuation and therefore emphasize the application of well-trained evacuation assistants to ensure a safe evacuation process. Overall, the results give important indications to improve evacuation situations by avoiding critical situations in which persons tend to become unconfident and therefore become incapable of action.

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