*Journal of the International Neuropsychological Society* (2021), **27**, 1015–1023

doi:10.1017/S135561772000140X

# Behaviors of Concern after Acquired Brain Injury: The Role of Negative Emotion Recognition and Anger Misattribution

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(Received July 7, 2020; Final revision December 21, 2020; Accepted December 22, 2020; First Published Online January 14, 2021)

**Abstract**

**Objective:** Behavioral changes are common after acquired brain injury (ABI) and may be caused by social cognition impairments. We investigated whether impaired emotion recognition, specifically Negative Emotion Recognition (NER) and Anger Misattribution (AM), after ABI was related to behavioral problems, so-called Behaviors of Concern (BoC). **Method:** The study included 139 participants with ABI and 129 healthy controls. BoC was measured using four scales of the Brock Adaptive Functioning Questionnaire (BAFQ): Impulsivity, Aggression, Social Monitoring, and Empathy. Both self-ratings and informant ratings of BoC were obtained. Emotion recognition was measured with the Ekman 60 Faces Test (FEEST). A NER score was composed of the summed scores on Anger, Disgust, Fear, and Sadness. An AM score was composed of the number of facial expressions wrongly recognized as Anger. **Results:** Total FEEST scores in ABI participants were significantly worse than in healthy controls. The effect size is moderate. Informants rated significantly more problems in Social Monitoring and Empathy than participants. Effect sizes were small. Scores on FEEST total, NER, and AM were significantly correlated to informant ratings of Social Monitoring. Correlations were weak to moderate. **Conclusions:** Worse NER and more profound AM were related to more informant-rated problems in social monitoring. In addition, informants rated more problems in social monitoring and empathy than participants. This strongly suggests problems in self-awareness in ABI participants. Consequently, social cognition tests and informant ratings should be used in clinical practice to improve the detection and treatment of BoC after ABI.

**Keywords:** Problem behavior, Social cognition, Emotion recognition, Brain injuries, Subarachnoid hemorrhage, Traumatic brain injury

## INTRODUCTION

Traumatic brain injury (TBI) and subarachnoid hemorrhage (SAH) are serious and sudden injuries to the brain. People who survive these acquired brain injuries (ABI) often encounter long-term cognitive, emotional, and behavioral problems, which can negatively affect daily life functioning, social participation, and quality of life (Al-Khindi et al., 2010; Buunk, Groen, Veenstra, & Spikman, 2015; De Rooij, Linn, Van Der Plas, Algra, & Rinkel, 2007; Dikmen, Machamer, Powell, & Temkin, 2003; Levin, Grossman, Rose, & Teasdale, 1979).

Behavioral problems are considered especially important in determining the quality of long-term recovery (Brooks, 1990), as they can be severe and persistent (Buunk et al., 2017; Spikman, Timmerman, Coers, & van der Naalt, 2015). Behavioral problems can have a serious impact on participation: many TBI and SAH patients fail to return to work or to maintain meaningful social relationships (Brooks, Mckinlay, Symington, Beattie, & Campsie, 1987; Buunk et al., 2015). For relatives of patients, behavioral changes are often a great burden, more than physical or cognitive impairments (Brooks, Campsie, Symington, Beattie, & McKinlay, 1986; Kinsella, Packer, & Olver, 1991). Behaviors of Concern (BoC) are those behaviors that have a significant negative impact on the daily functioning and quality of life of individuals and their close relatives (Hicks et al., 2017). Examples of BoC are aggressive behavior, apathy, and sexually inappropriate behavior. Aggression in particular is associated with a greater risk of violent criminality in

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patients with TBI (Williams et al., 2018). BoC was demonstrated in 70.5% of moderate–severe TBI patients, with verbal aggression and socially inappropriate behavior being most common (Hicks et al., 2017). In a recent study on long-term BoC, mild behavioral disturbances were found in 76% of TBI patients, while 24% of patients displayed serious behavioral disturbances (Timmer, Jacobs, Schonherr, Spikman, & van der Naalt, 2020). In a study by Buchanan, Elias, and Goplen (2000), the majority of SAH patients indicated significant negative behavioral changes. Behavioral changes are often accompanied by impaired self-awareness, which has been demonstrated in both TBI and SAH patients (Buchanan et al., 2000; Hütter & Kreitschmann-Andermahr, 2014; Spikman & Van Der Naalt, 2010). For example, ABI patients with behavioral problems rate their social competency significantly better than their relatives (Bach & David, 2006). Further, TBI patients tend to underreport behavioral difficulties in comparison with physical or cognitive problems (Hart, Sherer, Whyte, Polansky, & Novack, 2004). This lack of insight limits possibilities to assess the presence and frequency of such problems when only self-report measures are used. The level of self-awareness is unrelated to the severity of brain injury (Bach & David, 2006).

In recent years, there is increasing evidence that impairments in social cognition are underlying behavioral problems after brain injury (Nijsse, Spikman, Visser-Meily, de Kort, & van Heugten, 2019; Spikman et al., 2013). Social cognition refers to the cognitive abilities needed to recognize relevant social information, using this to understand the behavior of others and to react appropriately in social situations (Adolphs, 2001; Amodio & Frith, 2006; Beer, John, Scabini, & Knight, 2006). Deficits in social cognition have been demonstrated in both TBI and SAH patients (Buunk et al., 2017; McDonald, 2013).

An essential component of social cognition is emotion recognition, which has also shown to be critical for behavior regulation (May et al., 2017; Neumann, Malec, & Hammond, 2017; Spikman et al., 2013). Previous research demonstrated impaired emotion recognition in TBI and aneurysmal subarachnoid hemorrhage (aSAH) patients as compared to healthy controls (Buunk et al., 2016; Spikman, Timmerman, Milders, Veenstra, & Van Der Naalt, 2012). A trend toward emotion recognition impairments was also found for angiography-negative subarachnoid hemorrhage (anSAH) patients (Buunk et al., 2016). Specifically, negative facial expressions serve as social reinforcers that condition people to avoid engaging in behaviors that elicit these expressions in others (Hunnikin, Wells, Ash, & van Goozen, 2020). An inability to recognize negative emotional expressions may, therefore, result in people not adequately adjusting their behavior to other's reactions. This is important to consider since Negative Emotion Recognition (NER) is particularly affected in people with brain injury (Croker & McDonald, 2005; Hopkins, Dywan, & Segalowitz, 2002; Radice-Neumann, Zupan, Babbage, & Willer, 2007; Rapcsak et al., 2000). Additionally, the tendency to falsely perceive negative signals may also result in inappropriate behavior, such as an unwarranted hostile reaction (e.g., starting an argument or verbal or physical aggression). The tendency to make attributions that are significantly more negative than the attributions of the general population is termed negative attribution bias. Negative attribution bias is a clinical problem that has been found in TBI patients (Neumann, Malec, & Hammond, 2015). A negative attribution bias is also found to be related to interpersonal dysfunction (Carton, Kessler, & Pape, 1999). Normally, perceiving others' emotional expressions, particularly angry expressions, leads to response reversal (Blair, 2003). Response reversal comprises the modulation of current behavior as a response to observed stimuli. Disruption in this type of reaction, for example, in the form of Anger Misattribution (AM), may lead to problems in modulating behavior based on social cues, which can result in BoC.

The aim of the present study was to investigate whether impaired recognition of negative emotions and AM is related to BoC after TBI and SAH. Additionally, we studied self-awareness in participants to draw conclusions about the reliability of self-ratings. This knowledge is expected to contribute to a better understanding of the nature of BoC after ABI. Furthermore, it may support the use of emotion recognition tests as instruments that allow timely signaling of patients at risk for behavioral problems.

## METHODS

### Participants

This study included a convenience sample of 139 participants with ABI (59 patients with TBI and 80 patients with SAH) who were included in previous studies. Participants were admitted to the University Medical Center Groningen (UMCG) and were in the chronic phase after injury, with a mean since injury of 5.3 years ($SD = 6.2$). The TBI group consists of participants with moderate-to-severe TBI, classified by a Glasgow Coma Scale (GCS) score below 13 and/or a posttraumatic amnesia duration of at least 24 h. These participants were referred for rehabilitation due to problems in social functioning following TBI. The SAH group consists of participants with both aneurysmal ($n = 59$) and angiographically negative ($n = 22$) SAH. Patients with a traumatic SAH are not included in this group, since they are likely to have additional brain damage. Informants of participants with ABI were also included. Informants generally were family members or close friends of the participants. An informant had to have close and frequent contact with the participant to report on the subject, as judged by the researchers. A total number of 129 healthy participants were included. They had previously been tested for standardization research of the Ekman 60 Faces Test of the Facial Expressions of Emotion – Stimuli and Tests (FEEST) (Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). All participants were aged 18 years or older and had sufficient proficiency in the Dutch language. The study was approved by the Medical Ethical Committee of the UMCG and was conducted in accordance with the Declaration of Helsinki. All participants gave written informed consent.

## Demographic and Neurological Data

Demographic data (sex, age), time since injury, TBI severity, SAH severity (WFNS; World Federation of Neurological Surgeons; Teasdale et al., 1988), and aneurysm location were obtained from the participants' medical records. TBI severity was dichotomized in moderate (GCS 9–12) and severe TBI (GCS 3–8). For the severity of the clinical condition of SAH participants, WFNS scores 1–3 were classified as "low" and WFNS scores 4–5 were classified as "high". The Dutch Verhage scale was used to classify the level of education, ranging from 1 (no primary school) to 7 (university) (Verhage, 1964). The TBI group consisted of participants with moderate-to-severe TBI, while the SAH group mainly included participants with a low WFNS score. All participants were in the chronic phase after injury, with a mean time since injury of 8.1 years ($SD = 8.2$) in the TBI group and 2.8 years ($SD = .6$) in the SAH group. Demographic and injury-related characteristics of the TBI group, SAH group, and healthy controls are displayed in Table 1.

## Behaviors of Concern

The Brock Adaptive Functioning Questionnaire (BAFQ) (Dywan & Segalowitz, 1996) was used to measure BoC, whereby only the subscales that measured BoC according to the definition of Hicks et al. (2017), namely a behavior that has a significant negative impact on the daily functioning and quality of life of both individuals and their close relatives, were taken into account. This included increased impulsivity and aggression and decreased socially adequate behavior and empathy, measured using four domains of the BAFQ: Impulsivity (seven questions), Aggression (five questions), Social Monitoring (seven questions), and Empathy (five questions). Each question was scored on a scale from 1 (almost never) to 5 (almost always). For Aggression and Empathy, a score of ≥11 indicated problems, while for Impulsivity and Social Monitoring, a score of ≥15 indicated problems. These cutoffs distinguish between people with and without problems. An example question of the Impulsivity scale is "Are you making inappropriate comments or blurting out things you shouldn't have said?", while an example of the Aggression scale is "Are you going to throw things or break things when you're frustrated?". The Social Monitoring scale includes questions such as "Are you a little too close to someone when you are talking to them?" and "Do you not understand jokes or stories that make other people laugh?". Finally, a question of the Empathy scale is: "Would you notice if someone else is feeling exhausted or concerned?". The Social Monitoring and Empathy scales contain mirror items. The internal consistency of the BAFQ is adequate ($\alpha = .92$). The BAFQ has both a self and an informant version, the latter being filled in by a close relative of the participant. A significant difference between scores on the self and informant version of the BAFQ (with participants reporting lower scores than informants) may be interpreted as an indication of impaired self-awareness of the participant.

## Emotion Recognition

Emotion recognition was measured using the FEEST (Young et al., 2002). In this test, 60 facial expressions of the emotions Anger, Disgust, Fear, Sadness, Happiness, and Surprise are shown, whereby the participant has to select the correct label for the emotion. The total score ranges from 0 to 60 (maximum score of 10 per emotion), with higher scores indicating better emotion recognition. The FEEST is a reliable and valid test for the assessment of emotion recognition (Voncken, Timmerman, Spikman, & Huitema, 2018; Young et al., 2002). In the current study, scores on the emotions Anger, Disgust, Fear, and Sadness were summed and labeled as NER. The maximum score is 40. AM is defined as the number of facial expressions (Disgust, Fear, Sadness, Happiness, and Surprise) wrongly recognized as Anger. The maximum score is 50.

## Statistical Analyses

Analyses were performed with the Statistical Package for the Social Sciences (SPSS), Version 23.0. Descriptive statistics, including means, standard deviations, and percentages were calculated for participant characteristics. Differences between the (sub)groups were analyzed by means of $t$ tests, Mann–Whitney U tests, and chi-square tests. To analyze associations between BoC, NER, and AM, Spearman correlations were calculated because of the non-normal distribution. An α level of .05 was set for all analyses. Effect sizes were measured using Cohen's d (Cohen, 1988). In the case of multiple comparisons, Holm–Bonferroni corrections were used (Holm, 1979).

## RESULTS

Participants with ABI and healthy controls were well matched on sex ($\chi^2 = 3.193$, $p = .074$), age ($t = -.79$, $p = .432$), and level of education ($t = 1.66$, $p = .10$). The difference in mean emotion recognition score for men ($M = 46.48$, $SD = 5.92$) and women ($M = 48.11$, $SD = 6.17$) was significant ($t = -2.10$, $p = .037$). Differences between men and women on NER ($t = -1.71$, $p = .088$) and AM ($t = .27$, $p = .787$) were not significant. Table 2 shows that participants with ABI performed significantly worse on overall emotion recognition and NER as compared to healthy controls. The effect sizes were moderate. Participants' scores on recognition of Anger and Fear were also significantly lower than in the control group. The effect sizes were small. We found no differences between SAH and TBI participants in terms of emotion recognition, NER, and AM. For this reason, data for the TBI group and SAH group were taken together for further analyses.

Table 3 displays the percentage of problems and the mean scores on the BAFQ scales, as rated by participants with ABI and informants. For Social Monitoring and Empathy, significant differences were found between the self- and informant ratings, with informants indicating more problems. Effect sizes were small. Spearman correlations between the BAFQ scales were calculated and were all found to be significant ($p < .000$).

**Table 1.** Characteristics of TBI group, SAH group, and controls

| | TBI ($n = 59$) | SAH ($n = 80$) | Total ABI ($n = 139$) | Controls ($n = 129$) |
|---|---|---|---|---|
| Sex, number of women (%) | 10(16.9) | 50(62.5) | 60(43.2) | 42(32.6) |
| Age in years, M(*SD*) | 43.2(13.3) | 55.8(10.0) | 50.5(13.0) | 49.2(13.6) |
| Education (Verhage), M(*SD*) | 5.0(1.0) | 4.8(1.2) | 4.9(1.1) | 5.1(1.2) |
| Time since injury in years, M(*SD*) | 8.1(8.2) | 2.8(.6) | 5.3(6.2) | |
| TBI severity (GCS), (%) | | | | |
| Moderate | 22(37.3) | | | |
| Severe | 37(62.7) | | | |
| SAH severity (WFNS), (%) | | | | |
| Low | | 66(82.5) | | |
| High | | 14(17.5) | | |

TBI, traumatic brain injury; SAH, subarachnoid hemorrhage; ABI, acquired brain injury; GCS, Glasgow Coma Scale; WFNS, World Federation of Neurological Surgeons.

**Table 2.** Emotion recognition in participants with ABI and healthy controls

| | Participants | Controls | | | TBI | SAH | | |
|---|---|---|---|---|---|---|---|---|
| | *M*(*SD*) ($n = 139$) | *M*(*SD*) ($n = 129$) | Z | Cohen's d | *M*(*SD*) ($n = 59$) | *M*(*SD*) ($n = 80$) | Z | Cohen's d |
| Anger | 7.5(2.0) | 8.2(1.5) | **−3.07*** | .40 | 6.9(2.1) | 7.9(1.8) | −2.60 | .51 |
| Fear | 5.6(2.3) | 6.4(2.4) | **−2.59*** | .34 | 5.7(2.4) | 5.5(2.3) | −.38 | .09 |
| Disgust | 7.1(2.4) | 7.8(1.9) | −1.83 | .32 | 6.8(2.5) | 7.4(2.3) | −1.60 | .25 |
| Sadness | 6.7(2.2) | 7.3(1.7) | −2.22 | .31 | 6.2(2.1) | 7.0(2.2) | −2.10 | .37 |
| Happiness | 9.8(.6) | 9.9(.5) | −.66 | .18 | 9.7(.8) | 9.9(.4) | −.74 | .32 |
| Surprise | 8.7(1.5) | 8.9(1.1) | −.85 | .15 | 8.6(1.6) | 8.7(1.4) | −.51 | .07 |
| Total | 45.3(7.2) | 48.4(4.7) | **−3.28*** | .51 | 43.9(7.4) | 46.3(6.9) | −2.04 | .34 |
| NER | 26.8(6.5) | 29.6(4.7) | **−3.37*** | .49 | 25.6(6.7) | 27.8(6.2) | −1.87 | .34 |
| AM | 2.7(2.3) | | | | 3.3(2.7) | 2.4(2.1) | −1.71 | .37 |

ABI, acquired brain injury; TBI, traumatic brain injury; SAH, subarachnoid hemorrhage; NER, Negative Emotion Recognition; AM, Anger Misattribution. Mann–Whitney U tests were used to compare the results.
*Correlation is significant after Holm–Bonferroni correction.

Spearman correlations for the self-rated scales were Impulsivity−Aggression ($r = .63$), Impulsivity−Social Monitoring ($r = .39$), Impulsivity−Empathy ($r = .31$), Aggression−Social Monitoring ($r = .30$), Aggression−Empathy ($r = .31$), Social Monitoring−Empathy ($r = .61$). Spearman correlations for the informant-rated scales were: Impulsivity−Aggression ($r = .40$), Impulsivity−Social Monitoring ($r = .44$), Impulsivity−Empathy ($r = .30$), Aggression−Social Monitoring ($r = .31$), Aggression−Empathy ($r = .34$), Social Monitoring−Empathy ($r = .58$).

Scores on FEEST total, NER, and AM were not related to self-ratings of BoC (Table 4). However, more problems on informant ratings of Social Monitoring were related to significantly lower scores on FEEST total and NER. More problems on informant ratings of Social Monitoring were also related to a significantly higher score on AM. Correlations were weak to moderate in range. Thus, worse NER and more misattributions of anger are related to more problems in Social Monitoring as reported by informants.

## DISCUSSION

The current study investigated the relationship between impaired emotion recognition and BoC in participants with ABI. Emotion recognition was clearly impaired in participants with ABI when compared to healthy controls. We were particularly interested in two aspects of emotion recognition: NER and AM. We found a significant relation between one BoC, namely social monitoring, as rated by informants, and these two aspects of emotion recognition. More problems in social monitoring were related to worse NER and more profound AM. No relation with other BoC was found. In addition, informants rated significantly more social monitoring and empathy problems than participants themselves, suggesting problems in self-awareness in participants with ABI.

In line with previous findings, we found that both TBI and SAH participants performed worse on measures of emotion recognition compared to a group of healthy controls (Buunk et al., 2017; Spikman et al., 2013). Participants scored lower on recognition of Anger and Fear, NER, and overall emotion

https://doi.org/10.1017/S135561772000140X Published online by Cambridge University Press

**Table 3.** Differences in means of self- and informant-rated BoC in participants with ABI

| | Self (%) | Informant (%) | Self *M*(*SD*) | Informant *M*(*SD*) | z | Cohen's d |
|---|---|---|---|---|---|---|
| Impulsivity | 13.2 | 12.7 | 10.7(3.3) | 10.6(3.3) | −.80 | .03 |
| Aggression | 13.2 | 11.5 | 8.1(2.7) | 7.7(2.4) | −1.49 | .16 |
| Social monitoring | 54.4 | 64.2 | 15.4(4.1) | 16.7(5.1) | **−2.65*** | .28 |
| Empathy | 54.4 | 61.2 | 10.9(3.8) | 12.4(5.0) | **−3.30*** | .34 |

ABI, acquired brain injury.
Wilcoxon signed-ranks tests was used to compare the means.
*Difference is significant after Holm–Bonferroni correction.

**Table 4.** Spearman correlations between BoC, NER, and AM in participants with ABI

| | Impulsivity | Aggression | Social Monitoring | Empathy |
|---|---|---|---|---|
| FEEST total | | | | |
| Self | −.01 | .11 | −.10 | −.13 |
| Informant | −.14 | .12 | **−.36*** | −.20 |
| NER | | | | |
| Self | .01 | .10 | −.12 | −.14 |
| Informant | −.11 | .13 | **−.34*** | −.17 |
| AM | | | | |
| Self | .12 | .05 | .08 | .16 |
| Informant | .18 | .02 | **.27*** | .07 |

FEEST, Ekman 60 Faces Test of the Facial Expressions of Emotion – Stimuli and Tests; NER, Negative Emotion Recognition; AM, Anger Misattribution; ABI, acquired brain injury.
*Correlation is significant after Holm–Bonferroni correction.

recognition. Participants displayed the lowest scores on fear recognition, but this was also the case for the healthy controls. This finding is in line with previous studies in patients with brain injury, which suggested that the recognition of negative emotions, fear in particular, is especially vulnerable (Croker & McDonald, 2005; Hopkins et al., 2002; Radice-Neumann et al., 2007; Rapcsak et al., 2000). Additionally, Ietswaart, Milders, Crawford, Currie, and Scott (2008) showed that healthy controls also had more difficulty recognizing negative emotions. Furthermore, when comparing the TBI and SAH groups, we found no differences in emotion recognition, NER, and AM.

This study shows BoC in a considerable percentage of SAH and TBI patients, which is in accordance with previous research (Al-Khindi et al., 2010; Hicks et al., 2017; Timmer et al., 2020). Problems in impulsivity and aggression were experienced by 13.2% of participants, while 54.4% of participants experienced problems in social monitoring and empathy. Informants observed problems in impulsivity in 12.7% of participants and problems in aggression in 11.5% of participants, while problems in social monitoring and empathy were observed more often, in 64.2% and 61.2% of participants, respectively. Interestingly, when comparing the mean scores, we found that informants rated significantly more problems in social monitoring and empathy than participants. This difference was not found for the other BoC. In contrast to aggression and impulsivity, problems in social monitoring and empathy can be noticed in a social situation only. This could explain why they are more often noticed by informants. Besides, these problems can also be more subtle than aggressive behavior. However, this does not explain why informants observe significantly more problems in social monitoring and empathy than participants. This difference in observation, together with the fact that NER and AM were not related to any of the self-reported BoC measures, suggests problems in self-awareness in patients with ABI. This is not surprising since behavioral changes are often accompanied by impaired self-awareness (Hart et al., 2004; Spikman & Van Der Naalt, 2010). Impaired self-awareness hampers patients to understand and accept their limitations (Feeney, 2010). This may lead to frustration as they attempt to traverse boundaries they perceive to be unfairly placed upon them, leading to more BoC (Hicks et al., 2017).

Another finding of this study is that impaired emotion recognition and impaired NER were related to the presence of socially inadequate behavior, as rated by informants. The Social Monitoring scale measures to which extent participants are able to detect social cues and adjust their behavior accordingly. Emotions are important social cues, therefore, emotion recognition can be considered a key element in social monitoring (Pickett, Gardner, & Knowles, 2004). Since we conducted correlation analyses, no causal explanation can be provided. However, because emotion recognition is considered important for intact social behavior and is frequently impaired in TBI and SAH patients, impairments in emotion recognition are expected to underlie problems in social monitoring. This assumption is supported by studies showing a positive effect of emotion recognition training on behavioral problems after ABI (Radice-Neumann, Zupan, Tomita, & Willer, 2009; Westerhof-Evers et al., 2017).

In addition, AM was also associated with more informant-rated problems in social monitoring. This is in line with a study by Cohen, Nienow, Dinzeo, and Docherty (2009), who reported that schizophrenic patients who misinterpret facial emotions as being angry tend to have poorer social functioning than other patients. No associations of NER and AM with aggression, impulsivity, and empathy were found in our study. This is inconsistent with a study by Neumann et al. (2015), which indicated that the more TBI patients perceived other people's behaviors as intentional, hostile, or blameworthy, the more irritated and angry they felt. Even though Neumann et al. (2015) examined judgments of scenarios not facial expressions, it would be expected that the misattribution of anger to facial expressions would also be related to irritation and anger and in turn to more aggression. On the other hand, there may be differential contributions of the severity of brain injury and other factors, such as post-traumatic disorder (PTSD), to anger and aggression. Previous research found frontal abnormalities on acute stage CT in moderate–severe TBI patients to be associated with long-term BoC (Spikman et al., 2015). However, anger is also a prominent symptom of PTSD and depression (Besharat, Nia, & Farahani, 2013; Williamson, Heilman, Porges, Lamb, & Porges, 2013). Patients with TBI and SAH have a higher risk of both PTSD and depression, which is related to increased aggression (Hedlund, Zetterling, Ronne-Engström, Carlsson, & Ekselius, 2011; Perroud, Baud, Mouthon, Courtet, & Malafosse, 2011; Stein et al., 2019; Taft, Creech, & Murphy, 2017). That aggression is not solely related to the severity and location of brain damage is supported by a recent study of Timmer et al. (2020), who showed that anger (49%), verbal aggression (11%), and physically violent behavior (1.9%) occur in mild TBI patients who have very limited to no brain damage. In comparison, moderate-to-severe TBI patients experienced similar amounts of anger (40%), verbal aggression (10%), and physically violent behavior (.8%).

Furthermore, a possible reason for not finding stronger associations between NER and AM and other BoC (besides social monitoring) may be the possibly limited validity of the subscales of the BAFQ. The BAFQ only has a few items that address each BoC and may, therefore, not capture them comprehensively. At the same time, the lack of a significant relation between emotion recognition and empathy in our study could be explained by the complexity of the construct empathy. Empathy involves not only a recognition and understanding of another person's emotional state (cognitive component), but also the affective experience of this emotional state (affective component) (Decety & Jackson, 2004). The BAFQ Empathy scale includes questions that only measure the affective component, thereby assuming the cognitive component is intact. However, understanding of another person's emotional state is crucial for intact empathy and requires intact social cognition.

The main limitation of this study concerns the comparability of the participants. The group of participants with ABI consists of a TBI group and a SAH group that differ in various domains. First, the TBI group only included participants with a relatively severe clinical condition, while the SAH group was more diverse and also included participants with a relatively mild initial clinical condition. Second, the TBI participants were referred for rehabilitation with problems in social functioning, while there was no such selection for the SAH participants. Since the TBI participants had preexisting problems in social functioning, their performance cannot be generalized to the broader population of persons with moderate-to-severe TBI. Third, mean time since brain injury was longer in the TBI group (8.2 years) than in the SAH group (4.8 years). However, recovery of emotion recognition deficits over time is expected to be minimal based on previous research (Ietswaart et al., 2008). Furthermore, groups are trending toward a significant difference in sex distribution. This is a concern knowing that sex does play a role in emotion recognition, with women outperforming men on emotion recognition tasks (Olderbak, Wilhelm, Hildebrandt, & Quoidbach, 2019; Thompson & Voyer, 2014). In the current study, women scored significantly higher on general emotion recognition, but not on NER and AM.

Future research should address the reliability and validity of the BAFQ and the use of individual subscales. Besides, more research into the treatment options of ABI patients displaying BoC needs to be conducted. Impaired self-awareness is recognized as a limiting factor in functional recovery and rehabilitation outcomes (Prigatano, 1992). It should, therefore, be taken into account in the development of rehabilitation programs for ABI patients displaying BoC. The Treatment for Impairments in Social Cognition and Emotion Regulation (T-ScEmo) was shown to be effective in improving aspects of social cognition, including emotion recognition, as well as proxy-rated empathic behavior in moderate-to-severe TBI patients (Westerhof-Evers et al., 2017). Although the results can only be generalized to patients with moderate-to-severe TBI, it is deemed likely that the findings are replicable in other patient groups with ABI. More research into the effective components and the generalizability of this promising intervention needs to be performed. Another finding of Westerhof-Evers et al. (2017) was that the T-ScEmo group rated the relationship quality with informants to be higher than the control group. Following this finding, it would be interesting to find out whether relationship quality between participant and informant has an effect on the number of BoC reported by informants. To conclude, a history of untreated brain injury predisposes individuals at risk toward delinquent and violent behavior (León-Carrión & Ramos, 2003). This suggests that rehabilitation targeted at improving aspects of social cognition and social behavior for ABI patients could also be an effective method for crime prevention.

In conclusion, problems in emotion recognition, specifically impairments in NER and AM, were related to socially inadequate behavior in participants with ABI. Worse NER and a more pronounced AM were only associated with problems in social monitoring according to informant ratings, not with self-rated problems. Combined with the finding that informants rated significantly more problems in social monitoring and empathy, this suggests problems in participants' self-awareness. This highlights the need to use emotion recognition tests and informant ratings in clinical practice to improve the detection and treatment of BoC after ABI.

## ACKNOWLEDGMENTS

There was no financial support for this research.

## CONFLICT OF INTEREST

The authors report no conflicts of interest.

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