The Effect of Brief Situational Awareness Training in a Police Shooting Simulator: An Experimental Study

Evelyn-Rose Saus
Department of Psychosocial Science
University of Bergen, Norway

Bjørn Helge Johnsen and Jarle Eid
Department of Psychosocial Science
University of Bergen, Norway
and the Royal Norwegian Navy

Per Ketil Riisem and Rune Andersen
Department of Education
The Norwegian Police University College
Oslo, Norway

Julian F. Thayer
Department of Health Psychology
The Ohio State University

The aim of this study was to investigate the effect of situational awareness (SA) training in a shooting simulator. Forty 1st-year students from the Norwegian Police University College participated in this study. They were divided into 2 groups and matched with respect to sex and previous weapon experience. The SA-trained group received scenario-based training with freeze technique and reflection based on the
SA stages, whereas the control group received skill training. During the test phase SA was measured both subjectively and objectively and performance was measured by the number of shots fired and number of hits. The results showed that both subjective and observer ratings reported the SA-trained group to have higher SA. This was also true for performance, and the SA-trained group showed less mental workload measured as suppression of heart rate variability during the execution of the mission. These results indicate that brief SA-specific training in a shoot–not shoot simulator can improve police cadets’ SA in critical situations.

There is increased international focus on the use of force in modern police work. In particular, the use of weapons to control critical situations has been heavily debated in the media. Situations involving the use of firearms are often characterized by a rapidly evolving scenario, complex environment, a great deal of uncertainty, and a high degree of fear. For a police officer these factors make it extremely difficult to decide whether or not to shoot. Such demanding situations take a heavy toll on the mental capacity of the police officer, and the same factors can be identified in military operations. Thus, a need for experimental studies on methods of education and training of military populations and police officers has evolved.

One critical factor in making adequate decisions in critical situations is generating and maintaining situational awareness (SA; Endsley, 1999; Klein, 2000). SA refers to cognitive processes involved in perceiving and comprehending the meaning of a given environment. SA, in turn, enhances the capacity to make timely and effective decisions. A core element in these decisions is ability to project likely events in the near future (Matthews, Strater, & Endsley, 2004). Thus, SA is a conscious dynamic reflection of the situation, and its reflects the past, present, and future. Endsley (1988) proposed a three-stage model for SA, with each stage being a necessary (but not sufficient) precursor to the next level. The first level involves the fundamental perception of the elements of a particular environment. Further the officer has to understand the meaning of the percepted elements. This comprehension involves the second stage in the model, and the last stage represents the projection of future events. During a mission it is important for the police officer to be aware of the surroundings, like numbers of civilians and if there are any casualties. Based on this information the police officer might expect further events, such as a perpetrator with a weapon. This again will have implications for the officer’s decision making.

SA is closely linked to human decision making and performance, and can be critical to effective functioning in complex and dynamic environments (Endsley & Garland, 2000; Matthews et al., 2004). Svensson and Wilson (2002) showed that mission complexity affects workload, which affects both SA and performance. This link is often reported in aviation accidents resulting from inadequate situational assessment and SA (Garland, Wise, & Hopkin, 1999; Shebilske, Goettl, &
Garland, 2000). Studies of SA have also been conducted in environments like air traffic control rooms and different military settings (Matthews et al., 2004; Rodgers, Mogford, & Strauch, 2000). The profusion of information technology results in an increased cognitive workload. At the same time the environment can be constantly changing, giving rise to unexpected events (Matthews et al., 2004; Rodgers et al., 2000).

Research has documented SA’s fundamental role in skilled performance (Endsley & Bolstad, 1994; Endsley & Kaber, 1999). SA training may address both individual and team-level processes and behaviors. Both the use of simulators and training are interventions aimed at improving performance.

Today there are relatively few empirical outcome evaluations of SA training programs. One of the reasons is the focus on SA-oriented design and automation issues. Beyond automation, effective training can be achieved by improving the skills and knowledge critical for achieving good SA. Factors in individual training may involve higher order cognitive skills training, intensive briefings, use of structured feedback, and SA-oriented training programs, such as information seeking and training specifically focused to develop SA and decision making (see Endsley & Robertson, 2000, for an overview). Individual training should aim at improving critical information-seeking and information-processing behaviors (Salas, Prince, Baker, & Shrestha, 1995). This can be done by systematically exposing the individual to different scenarios with guided practice and feedback. For example, on a team level, Salas et al. (1995) recommended that SA training should focus on complex communication behaviors, team planning, and task-specific competencies, such as roles and position in the team.

Because there are few empirical studies on the effects of SA training, there is a need to empirically evaluate specific SA training techniques. One promising technique is the so-called freeze technique (Endsley, 1995). This technique involves stopping or “freezing” a simulated operational task at randomly chosen points in time. Queries are then made concerning the three levels of SA. This technique is largely nonintrusive and gives a good understanding of the individual’s SA, which again gives a more accurate measure of SA. Romano and Brna (2001) suggested that to improve performance, training must also offer the opportunity to reflect on one’s performance. Thus, by combining the freeze technique and reflection about a specific scenario one could study the effect of scenario-based SA training (Endsley, 1988).

One way to train SA is by the use of simulators. The use of simulation has become an important technology for skills training. Simulators can provide a safe learning environment and are regarded as a cost-effective training regime (White, Carson, & Wilbourn, 1991b). The scientific advantage of using simulators involves thorough control of the setting and the capacity to systematically manipulate training variables; for example, individuals can train under different levels of stress, time pressure, and workload. Virtual reality allows the presence of this type
of experimental control, and at the same time involves a high level of realism in the scenarios; such realism further increases generalizability of the results.

For police, lethal and nonlethal force are essential components in preparation for future violent confrontations. Such high-risk encounters are relatively infrequent field events that are difficult to examine in a natural setting. A simulator affords the possibility to study police shooting behavior in a controlled setting and may provide insight into the use of lethal force in the field.

SA as a theoretical concept involves basic cognitive processes like attention, perception, and decision making. A core element in these processes is the use of executive functions (Baddeley, 1986). Executive functions are responsible for human planning, reasoning, problem solving, decision making, and acting. Different aspects of executive control involve selecting, maintaining, updating, and rerouting of information (Shimamura, 2000). Thus, executive functions can be said to be basic processes in SA, and especially salient at levels two (perception of a situation) and three (projection in the near future).

Recent studies in our research group demonstrate a relation between individual differences in heart rate variability (HRV), as an index of neurovisceral integration (see Thayer & Lane, 2000), and executive function on continuous performance and working memory tasks (Hansen, Johnsen, Sollers, Stenvik, & Thayer, 2004; Hansen, Johnsen, & Thayer, 2003). Those individuals with greater HRV performed better on executive function tasks and better under conditions of threat (Hansen et al., 2003). Given the relation between SA and executive function, measures of individual differences in HRV may be useful in the understanding of SA. Based on our laboratory studies we would expect those persons with greater HRV to also show greater SA. Extending these findings to a simulation would offer an important generalization of our laboratory findings to a real-life situation and could have important implications for selection and training.

In addition, HRV is a promising dependent variable in studies of workload and cognitive demand. In response to increasing workload and cognitive demand, measures of vagally mediated HRV are reduced in a dose-dependent manner (Fairclough, Venables, & Tattersall, 2005). Increased load on working memory is associated with mental effort. It is therefore possible to use HRV as an indicator of mental effort (Backs & Seljos, 1994), where it is expected that HRV decreases as mental effort increases (Meshkati, 1988). Magnusson (2002) indicated that a pilot’s psychophysiological reactions in the simulator are similar to those in real flight, and that HRV is expected to decrease as mental effort increases. It is therefore possible to examine HRV in two distinct ways: (a) as an individual difference variable that may be related to SA, and (b) as a dependent variable that may index task demands and the interaction of task demands and individual differences.

The aim of this study was to investigate the effect of SA training in a shooting simulator. It was predicted that a group receiving scenario-based training combined with reflection on the SA stages would report higher SA and subjective
learning effects compared to a control group receiving skill training. Importantly, this training effect should also be reflected in observer ratings of SA. In addition, it has been suggested that SA is associated with improved performance and thus we predicted improved performance as indicated by a higher number of shots fired and more hits for the SA-trained group. Firing more is not always a good indicator of high SA. In this study this was done because the test scenario involved a setting where successful performance required participants to fire their weapon, and the firearms training simulator (FATS) did not stop the scenarios until a fatal shot was fired. Therefore, number of shots fired was used as a performance measure. Furthermore, the relations among SA, executive function, and HRV suggest that those persons with greater HRV would show evidence of greater SA. Finally, because SA has been related to the concept of mental workload, and HRV has been used as a measure of workload, we predicted that the SA-trained group would show less suppression of HRV during the execution of the mission compared to the control group.

**METHOD**

**Participants**

A total of 40 students (20 men and 20 women) from the first year of training at the Norwegian Police University College participated in the study. The mean age was 24.88 years (range = 20–33). The Police University College is a 3-year program that includes theoretical and practical courses related to modern policing. Sex, age, and previous experience with weapons were also recorded.

**Apparatus and Questionnaires**

Data were collected during mission training in a shoot–not shoot simulator (FATS). The simulator was situated in a room of 70 m², with a computerized movie projector and standard service weapons, retrofitted with a laser-emitting device to mark the impact of the weapon. The simulator used gas (CO₂) to simulate weapon recoil, and had noise-report capability. Although the simulator is set up for several weapons, this study only used the MP5 ( Heckler & Kock) as a weapon. The computer displayed realistic video-based simulated scenarios designed to test the student’s judgment and skill in the use of deadly force under stressful conditions. The system registered movements of the weapon, number of shots fired, and the effect of each bullet and point of impact.

Cardiovascular responses were recorded using an ambulatory monitoring system (AMS; Klaver, de Geus, & de Vries, 1994). The cardiac responses were measured using 1 cm Ag/AgCl ECG electrodes (Ultratrace, disposable pregelled electrodes). One electrode was placed over the jugular notch of the sternum, between
the collarbones, another was placed 4 cm under the left breast between the ribs, and
the third electrode was placed at the right lateral side between the two lower ribs.

SA was measured using two different self-report questionnaires, both translated
into Norwegian. The first questionnaire was the Situational Awareness Rating
Scale (SARS; Waag & Houck, 1994, adapted for use in a shooting simulator). The
Norwegian version consisted of 25 items (scored 1–6) concerning general traits,
and the SA dimensions of tactical planning, system operations, communication,
information interpretation, tactical decisions, and general tactic (see also Dalseg,
2000). An example of a general trait item was “I have good knowledge about
shooting.” An example SA item was “To what extent could you create a mental
model of the situation?” In a pilot study an internal consistency of .86 was found
(Dalseg & Johnsen, 2001). The second SA scale was the Situational Awareness
Behaviorally Anchored Rating Scale (SABARS). This questionnaire was a direct
subjective measure of SA, which was also utilized with expert-observer rating on
behaviors linked to SA in the specific context (Matthews, Beal, & Pleban, 2001).
The instrument consisted of 18 items divided into three dimensions: the partici-
pant’s awareness of own SA (e.g., “To what extent did you know your own re-
sources?”), awareness of the perpetrator (e.g., “To what extent did you know the
perpetrator’s placement?”), and the awareness of the mission (e.g., “To what extent
did you understand possible obstacles in performing your mission?”).

Both the SARS and the SABARS were administered in a subjective rating ver-
sion and an observer rating version. The SARS observer rating version consisted of
the 15 SA items only. The general trait items were excluded. Because the SABARS
questionnaire was behaviorally anchored, the observer rating version consisted of
the same 18 items as the subjective rating version.

In addition, the participants were asked two questions about learning and real-
ism in the situation (e.g., “To what extent did you learn from the experience?”;
scored 1–6) as well as four questions about training effects on decision making in-
volved in handling a critical situation involving weapon use (e.g., “To what extent
has the training given you an increased understanding of the rules and regulations
of weapon use?”; scored 1–6).

Procedure

Before the start of the experiment, participants read and signed an informed con-
sent statement. They were informed about their right to leave the experiment at any
time. No participants withdrew from the experiment. All were tested individu-
ally in the simulator at the Norwegian Police University College.

The participants were matched with respect to sex and previous experience us-
ing weapons, and then randomly assigned to either the test (SA-trained) or the con-
trol (skill-only) group. Both the SA-trained group and the control group consisted
of 20 participants.
This study consisted of two phases. During the training phase, the SA-trained group received scenario-based training in the simulator. The participants were armed with an MP5 during all sessions and each of the three sessions involved different missions in which the police might have to use the weapon, and others in which the preferred action was not to use a weapon. Every scenario involved a freeze technique, where the video was stopped and the participants were asked questions related to Endsley’s (1988) three levels of SA. During debriefing, after each session, participants were encouraged to reflect on the levels of SA and relate the scenarios to the rules and regulations of the use of weapons in the police force.

In the training phase, the control group got general information about the use of the simulator and practiced the use of MP5. The sessions consisted of training in marksmanship skills. Each target practice consisted of three different exercises with different targets, selection of targets, and permanent and mobile targets. The control group was asked to reflect on the rules and regulation of the use of weapons in the police force. The training sessions involved increased degree of difficulty. Time spent in the simulator as well as the number of sessions were identical for the two groups.

The test phase consisted of a simulated scenario for all the participants. After HRV electrodes were placed on the participants, the sequence of 5 min of baseline, preparing for the mission, the execution of the operation, and 5 min of recovery was performed on all participants. Suppression of vagal activity was used as an indication of workload. Vagal activity was measured as the root mean of the squared successive differences (HRV). This index of vagal innervations of the heart correlates highly (.90) with spectral derived indexes of parasympathetic drive to the heart (Hayano et al., 1991), and the suppression of HRV is frequently used as a measure of strain to the organism.

When preparing for the mission (preparation phase) the operational leader informed participants about the mission, and participants got the opportunity to ask questions concerning the mission. They also had time to prepare their weapon, protective gear, and radio. Then they completed the mission with freezing sessions that included questions about SA. Freeze sessions allowed the observer to evaluate participants’ SA levels.

SA data were collected by having the respondents fill in the self-report SA questionnaires. For the self-report SARS, nine summary scores were produced. These included a total summary score, which was the sum of all 25 items; the sum score of the 15 SA items only; and 7 dimension scores. In addition, sum scores of the learning and realism questions, as well as sum scores of effect of training on decision making were constructed for each participant. An expert observer was used to obtain external ratings of SA. The expert was an instructor in tactical weapon use recruited from the other Police University College in Norway. The observer had no information regarding which of the participants were exposed to
which conditions. The observer’s SARS rating was based on a summary score of
the 15 SA items. For both the subjective and observer SABARS versions, the sum
score for all 18 items was used, and there were also three sum scores for each of the
dimensions.

Performance was measured by number of shots fired and number of hits. This
was done because the test scenario involved a setting in which successful perfor-
mance required participants to fire their weapon. The FATS did not stop the scenar-
ios until a fatal shot was fired. Therefore, number of shots fired was used as a per-
formance measure. The experiment ended with a mission debriefing from both the
operational leader and the observer.

Design and Statistics
An independent group design with matched random assignment was used
(Cozby, 1993). T

 tests for independent samples were used to investigate differ-
ences between the two groups regarding SA and performance. The results were
also based on one-tailed tests due to the hypothesized direction of the means
(Ferguson, 1981). Differences in HRV were tested by using a 2 (SA-trained vs.
control group) × 4 (baseline vs. preparing vs. execution vs. recovery) analysis of
variance (ANOVA). The first factor was treated as a between-group factor and
the second as a within-groups factor. The relation among cardiovascular re-
sponses, SA levels, and outcome measures were investigated using Pearson
product–moment correlation.

RESULTS

Reliability Analyses
Analyses of the questionnaires showed a Cronbach’s alpha on the 25-item SARS
of .85 (external ratings = .96). The Cronbach’s alpha of the SABARS was .78 (ex-
ternal ratings = .89). The four items concerning decision making in critical situa-
tions revealed a Cronbach’s alpha of .68.

Effects of SA Training on Subjective Measures of SA
Analyses of the SARS questionnaire showed a higher level of subjective SA for the
SA-trained group compared to the control group, t(37) = –1.89, p < .05. This was
the case for the sum score on SA items only (see Figure 1). When separating the
SARS into the dimensions, a higher SA level was found in the trained group com-
pared to the control group on tactical decision making, t(37) = –2.14, p < .05, and
general tactics, t(37) = –2.31, p < .05.

On the SABARS questionnaire, higher scores were found on the dimension
concerning awareness of the perpetrator, t(35) = –1.75, p < 05, for the SA-trained
group (Figure 1). No other comparisons were significant.
Effects of SA Training on Observer Ratings

Figure 2 presents mean sum scores on observer ratings of SA. For the SARS summary score there was a significant difference between the groups, $t(38) = -3.52$, $p < .01$, in which the observer reported a higher level of SA in the SA-trained group. The observer ratings on the SABARS summary score, $t(33) = -2.65$, $p < .01$, showed a higher level of SA in the SA-trained group. The observer also reported higher SA levels in the SA-trained group compared to the control group on all the
subdimensions of SABARS: awareness of own situation, $t(33) = –2.84, p < .01$; awareness of the perpetrator, $t(33) = –1.94, p < .05$; and awareness of the mission, $t(33) = –2.54, p < .05$.

**Performance Measures**

The SA-trained group fired more shots, $t(34) = –2.82, p < .01$, and had a higher number of hits on target, $t(34) = –2.51, p < .05$, compared to the control group (see Figure 3).

**Learning and Training Effects on Decision Making**

The SA-trained group showed higher self-ratings of decision making involved in handling a critical situation, $t(37) = –1.85, p < .05$, compared to the control group. No other significant effects were found.

**Cardiovascular Responses**

Correlations between HRV during the four phases and SA measures were performed. As predicted, analyses showed a positive correlation between SA scores (SA items only) and HRV measured during the HRV preparation phase, $r(40) = .39, p < .01$. In addition, borderline correlations were found between HRV measured during the baseline and execution phases and SA scores on the SARS, $r(40) = .25, p < .06$, and $r(40) = .23, p < .07$, respectively. The same pattern occurred when using the total score on the SARS. Positive correlations were found between
SARS total and baseline measures of HRV, $r(40) = .27$, $p < .05$; recordings during the preparation phase, $r(40) = .43$, $p < .01$; as well as during the execution phase, $r(40) = .29$, $p < .04$. Significant correlations were also found between ratings of learning from the experience and HRV measured at baseline, $r(40) = .30$, $p < .03$ (one-tailed); during the preparation phase, $r(40) = .42$, $p < .01$; as well as during the execution phase, $r(40) = .32$, $p < .05$.

To investigate the effects of workload and cognitive demand, a Group (2 levels: SA-trained vs. control) × Experimental Phase (4 levels: baseline, preparation, execution, and recovery) ANOVA was performed. A main effect of the phase was found on the HRV data, $F(1, 3) = 11.7$, $p < .01$. A least significant different post hoc test showed a suppression of HRV from baseline to the preparation phase ($p < .01$). There was a further suppression of HRV from the preparation phase to the execution phase ($p < .03$), followed by a significant increase in HRV in the recovery phase ($p < .01$). To follow up a possible differential effect on the cardiovascular reactivity between the two groups, preplanned simple effects tests were used (Wilcox, 1987). The $t$ tests revealed that the SA-trained group did not show suppression of HRV from preparation through to the execution of the mission ($p < .05$).

Subjective Versus Observational Ratings of SA and Learning

Table 1 shows correlations between self-report measures of SA, observer measures of SA, and scores on subjective experience of learning, as well as effect on decision making in critical situations. As can be seen in Table 1, strong correlations were found between self-report and observer ratings of SA (all $p < .01$). Learning and decision making were not correlated to external ratings of SA. Further analyses showed that self-report ratings of SA were positively related to subjective feeling of learning: SARS total, $r(40) = .31$, $p < .05$; SA items only, $r(40) = .31$, $p < .05$; and the sum score SABARS, $r(37) = .37$, $p < .03$. Self-report subjective ratings of SABARS were borderline related to effect on decision making, $r(36) = .26$, $p < .06$.

SA Ratings and Performance

Tables 2 and 3 show Pearson product–moment correlations between self-report and observer ratings of SA and number of shots fired and number of hits on target. The tables show that both SA questionnaires and their subdimensions showed positive significant correlations with the number of shots fired. The only exceptions were the communication dimension on the SARS and awareness of the mission on the SABARS. Positive correlations between SA measures and number of hits were found on the sum scores of SA items only (one-tailed) and on the SARS total, as
### TABLE 1
Correlation Analysis for Subjective Versus Observational Ratings of SA and Learning

<table>
<thead>
<tr>
<th>Observer Ratings</th>
<th>SARS</th>
<th>Sum SABARS</th>
<th>Own</th>
<th>Perpetrator</th>
<th>Mission</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARS total</td>
<td>.53**</td>
<td>.48**</td>
<td>.44**</td>
<td>.28</td>
<td>.57**</td>
</tr>
<tr>
<td>SA items only</td>
<td>.54**</td>
<td>.48**</td>
<td>.44**</td>
<td>.29*</td>
<td>.57**</td>
</tr>
<tr>
<td>Sum SABARS</td>
<td>.40**</td>
<td>.43**</td>
<td>.34*</td>
<td>.26</td>
<td>.53**</td>
</tr>
<tr>
<td>Own</td>
<td>.29*</td>
<td>.26</td>
<td>.20</td>
<td>.12</td>
<td>.38*</td>
</tr>
<tr>
<td>Perpetrator</td>
<td>.38*</td>
<td>.45**</td>
<td>.40**</td>
<td>.29*</td>
<td>.51**</td>
</tr>
<tr>
<td>Mission</td>
<td>.25</td>
<td>.32*</td>
<td>.17</td>
<td>.23</td>
<td>.40**</td>
</tr>
<tr>
<td>Learning</td>
<td>.11</td>
<td>.05</td>
<td>.17</td>
<td>–.03</td>
<td>.09</td>
</tr>
<tr>
<td>Decision making</td>
<td>–.02</td>
<td>.17</td>
<td>.22</td>
<td>.12</td>
<td>.10</td>
</tr>
</tbody>
</table>

**Note.** $N = 40$. The table is separated in sum scores for SARS total and SA items only, sum score SABARS, and three dimensions: participant’s own awareness (own), awareness of the perpetrator (perpetrator), and awareness of the mission (mission). SA = situational awareness; SARS = Situational Awareness Rating Scale; SABARS = Situational Awareness Behaviorally Anchored Rating Scale.

* $p < .05$. ** $p < .001$.

### TABLE 2
Correlation Analysis Between Subjective Ratings of SA and Performance

<table>
<thead>
<tr>
<th>Subjective SA Ratings</th>
<th>Shots</th>
<th>Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>SARS total</td>
<td>.62**</td>
<td>.34*</td>
</tr>
<tr>
<td>SARS SA items only</td>
<td>.58**</td>
<td>.27*</td>
</tr>
<tr>
<td>General trait</td>
<td>.50**</td>
<td>.40**</td>
</tr>
<tr>
<td>Tactical planning</td>
<td>.52**</td>
<td>.19</td>
</tr>
<tr>
<td>System operations</td>
<td>.38*</td>
<td>.16</td>
</tr>
<tr>
<td>Communication</td>
<td>.10</td>
<td>.14</td>
</tr>
<tr>
<td>Information interpretation</td>
<td>.48*</td>
<td>.16</td>
</tr>
<tr>
<td>Tactical decision</td>
<td>.60**</td>
<td>.31*</td>
</tr>
<tr>
<td>General tactic</td>
<td>.34*</td>
<td>.28*</td>
</tr>
<tr>
<td>Sum SABARS</td>
<td>.39*</td>
<td>.23</td>
</tr>
<tr>
<td>Own</td>
<td>.34*</td>
<td>.23</td>
</tr>
<tr>
<td>Perpetrator</td>
<td>.33*</td>
<td>.11</td>
</tr>
<tr>
<td>Mission</td>
<td>.21</td>
<td>.17</td>
</tr>
</tbody>
</table>

**Note.** $N = 40$. The SARS data are separated in sum scores for SARS total and SA items only. SA items only are further separated for the seven dimensions. The SABARS data are divided in sum score SABARS and the three dimensions: participant’s own awareness (own), awareness of the perpetrator (perpetrator), and awareness of the mission (mission). Performance data are presented as mean number of shots fired (shots) and number of hits on target (hits). Correlation analysis for observer ratings of SA and performance measured in number of shots fired (shots) and number of hits on target (hits). SA = situational awareness; SARS = Situational Awareness Rating Scale; SABARS = Situational Awareness Behaviorally Anchored Rating Scale.

* $p < .05$. ** $p < .001$. 
well as the dimensions of general trait, tactical decision (one-tailed), and general tactics (one-tailed). Observer ratings showed a positive relation between both SARS and SABARS scores and number of hits on target (see Tables 2 and 3 for details).

**DISCUSSION**

The results of this study showed that the SA-trained group reported a higher level of subjective SA and decision making during a critical situation compared to the control group. Subjective ratings were confirmed by observer ratings. Furthermore, performance data showed that the SA-trained group recorded both a higher number of shots fired and a greater number of hits on target compared to the control group. Further analyses examined individual differences in SA and revealed positive correlations between SA as measured by both self-report and observers, and performance as indexed by number of shots fired and number of hits. The results also suggested that individual differences in HRV were associated with SA such that, consistent with our predictions, persons with higher resting HRV had higher SA. Finally, the results supported the predicted relation between task demands and HRV such that HRV decreased during the performance of the task but did so less for the SA-trained group.

The first aim of the study was to investigate the effect of SA training in a shooting simulator, where it was hypothesized that the SA-trained group would report higher levels of SA. It was expected that the SA training would increase SA and thus could develop comprehension, judgment concerning risk level, and better pro-

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**TABLE 3**

Correlation Analysis Between Observer Ratings of SA and Performance

<table>
<thead>
<tr>
<th>Observer Ratings of SA</th>
<th>Shots</th>
<th>Hits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sum SARS</td>
<td>.50**</td>
<td>.46**</td>
</tr>
<tr>
<td>Sum SABARS</td>
<td>.46**</td>
<td>.34</td>
</tr>
<tr>
<td>Own</td>
<td>.46**</td>
<td>.36*</td>
</tr>
<tr>
<td>Perpetrator</td>
<td>.33*</td>
<td>.26</td>
</tr>
<tr>
<td>Mission</td>
<td>.45**</td>
<td>.37*</td>
</tr>
</tbody>
</table>

*Note. N = 40. The SARS data are separated in sum scores for SARS total. The SABARS data are divided in sum score SABARS and the three dimensions: participant’s own awareness (own), awareness of the perpetrator (perpetrator), and awareness of the mission (mission). Performance data are presented as mean number of shots fired (shots) and number of hits on target (hits). Correlation analysis for observer ratings of SA and performance measured in number of shots fired (shots) and number of hits on target (hits). SA = situational awareness; SARS = Situational Awareness Rating Scale; SABARS = Situational Awareness Behaviorally Anchored Rating Scale.

*p < .05. **p < .001.
jection of future events. The latter could be important in unexpected and critical situations. This is in line with Orasanu, Dismukes, and Fischer (1993), who reported that experienced pilots appeared to spend time preflight planning, seeking information in advance, and data gathering. These actions can reduce workload in critical events, and are important for good SA. SA training can also facilitate construction of mental models, which are an important precursor for good SA (Endsley & Robertson, 2000).

We also expected higher SA for the SA-trained group because the training consisted of both shoot and not shoot scenarios and thorough debriefing with a focus on the participants’ decision making and understanding of the situation (Salas et al., 1995). As predicted, participants reported higher subjective SA on the sum score of the 15 SARS SA items. This result was also supported by the behaviorally anchored questionnaire (SABARS), on the awareness of the perpetrator dimension. Of course, a possible explanation can be that the SA-trained group members had their main focus on the perpetrator because the purpose of the mission was to identify and act against the perpetrator. It could also be that the SARS and SABARS measure distinct factors in SA. SARS combines assessment on many dimensions, including decision-making abilities, skills, and performance (Jones, 2000), whereas SABARS is directly linked to SA through relevant behavior.

This study created significant differences between the SA-trained and the control group in only three sessions. The use of both the freezing technique and reflection may have resulted in better opportunity to efficiently acquire knowledge and experience, which resulted in rapid improvement in SA. Experience can reduce the amount of resources required for specific tasks, which may result in more resources available for achieving SA (Endsley & Bolstad, 1994). These factors are also important in decision making, and there was also a difference between the groups concerning decision making in handling a critical situation. Again the SA-trained group reported higher ratings compared to the control group. Romano and Brna (2001) claimed that when training limited decision-making skills, there should be opportunity to reflect on actions and strategies to improve performance. Thus training in virtual environments should provide both skills and reflection. The results from this study support this suggestion.

In this study the participants were first-year students at the Norwegian Police University College and novices with regard to simulator training. It is possible that the effects seen here only occur among novices. Such an argument was forwarded by White et al. (1991b), who claimed that a trainer was effective for teaching marksmanship skills for those with minimal weapon expertise. Buffardi and Allen (1986) also concluded that high-fidelity simulators enhance the performance of low-ability students more than high-ability students. Future research should consider whether simulator training is valuable for experts in terms of performance and SA (White, Carson, & Wilbourn, 1991a).
In the literature there has been discussion of whether to use self-report or objective ratings of SA (Vidulich, Stratton, Crabtree, & Wilson, 1994). The high correlations between observer and self-report ratings support the use of self-report ratings in studies of factors influencing SA. However, the use of both self-report and observer ratings may give a more accurate measure of SA.

This study also predicted that the SA-trained group would perform better than the control group. Both the self-report and the observer ratings showed that this was true both for number of shots fired and number of hits. The positive correlations between self-reported SA and number of shots fired might be explained by the technical construction of the shooting simulator. It is constructed in such a way that the perpetrator does not fall and stop shooting unless he or she is hit by a lethal shot. It could be that the participants observed this, and fired more shots and had a higher number of hits because they were able to monitor when the threat was eliminated. Because of their higher SA, participants in the SA-trained group focused on the perpetrator and managed to fire more shots when the perpetrator opened fire. This is further supported by the fact that the SA-trained group reported higher SA on the awareness of the perpetrator dimension. These clear indications from both self-report and observer ratings support the notion that SA training leads to increased SA and subsequently to increased performance.

There was also evidence for individual differences in SA independent of training. Analyses revealed a positive correlation between the SA questionnaires and performance. This finding is in accordance with Svensson and Wilson (2002), whose model analysis showed a positive correlation between SA and performance. Also Svensson, Angelborg Thanderz, Sjoberg, and Olsson (1997) found positive correlation between performance in a flight task and SA. The results also give support to Endsley and Garland (2000), who emphasized high SA as an important factor for successful performance.

Individual differences in HRV were also found to be related to SA. This represents an important extension of laboratory-based studies in which persons with higher HRV performed better on tasks that tapped executive functioning (Hansen et al., 2004; Hansen et al., 2003). Given the literature suggesting that executive functioning is critical to SA, particularly the latter two stages, these results provide a real-world validation of our previous findings and suggest that individual differences in HRV could have important practical implications for performance of mission in critical tasks. The highest positive correlation was found between HRV recorded during preparation for the mission and self-reported SA. During the preparation phase the participants received the description of and orders for the mission. This could lead to an increase in mental effort and anxiety. Because mental effort and anxiety have been closely related to HRV (Thayer, Friedman, & Borkovec, 1996), it could explain why the effect was most dominant in this phase. A similar pattern was found for the relation between HRV and learning. Because learning also would rely on executive functioning, the previous reported link be-
tween HRV and executive functioning could explain these results. Further research will be necessary to explicate the consequences of these findings for selection and training. However, given that HRV can be manipulated via, for example, physical exercise with concomitant changes in performance, it may be possible to combine SA training with physical fitness training to optimize performance of mission personnel.

The results with respect to changes in HRV as a function of cognitive demand, and the relatively lesser impact as indexed by less HRV suppression during the execution phase of the simulator task in the SA-trained group also suggest ways in which SA training and training to increase HRV might be usefully combined. For example, our previous work has shown that persons with higher HRV were more stress tolerant and showed a smaller cortisol response to cognitive challenge (Johnsen, Hansen, Sollers, Murison, & Thayer, 2002). Cortisol has been shown to decrease performance on executive function tasks and thus provides one pathway by which increased SA and the attendant increased HRV and decreased cortisol response could work to buffer individuals from the adverse effects of cognitive demand.

The positive relation between SA and performance may also be evidence of the validity of our measures of SA. Results from this study showed that both the self-report and observer SA questionnaires capture expected differences and relations with performance. This gives an indication of validity of the questionnaires used (Johnsen & Hugdahl, 1990). The questionnaires also showed acceptable reliability indicated by Cronbach’s alpha for self-report ratings of SARS and SABARS. The alpha values were .78 and .85, respectively.

In summary, this study showed that brief SA-specific training in a shoot–not shoot simulator improved police cadets’ SA. This was the case for both self-report and observer ratings. SA-specific training also resulted in increased performance. The SA training was superior to the skill training in the simulator because previous experience was matched in the two groups. The only difference was that one group conducted skill training (marksmanship) and the other group was involved in scenario-based SA-specific training using freeze techniques and reflection based on the SA stages. The finding that HRV was related to SA opens several potentially interesting lines of investigation with respect to selection and training. Future work is needed to illuminate the mechanisms responsible for these effects and how they might be utilized in the service of improved performance in critical situations.

REFERENCES


