How Accurate Is Information Transmitted to Medical Professionals Joining a Medical Emergency? A Simulator Study

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Objective: This study used a high-fidelity simulation to examine factors influencing the accuracy of 201 pieces of information transmitted to nurses and physicians joining a medical emergency situation. **Background:** Inaccurate or incomplete information transmission has been identified as a major problem in medicine. However, only a few studies have assessed possible causes of transmission errors. **Method:** Each of 20 groups was composed of two or three nurses (first responders), one resident joining the group later, and one senior doctor joining last. Groups treated a patient suffering a cardiac arrest. **Results:** Multilevel binomial analyses showed that 18% of the information given to newcomers was inaccurate. Quantitative information requiring repeated updating was particularly error prone. Information generated earlier (i.e., older information) was more likely to be transmitted inaccurately. Explicitly encoding information to be transmitted after the physicians arrived at the scene enhanced accuracy, supporting transfer-appropriate processing theory. **Conclusion:** Information transmitted to nurses and physicians who join an ongoing emergency is only partly reliable. Therefore, medical professionals should not take accuracy for granted and should be aware of the nature of transmission errors. **Application:** Medical professionals should be trained in adequate encoding of information and in standardized communication procedures with regard to error-prone information. In addition, technical devices should be implemented that reduce reliance on memory regarding information with error-prone characteristics.

INTRODUCTION

Consider a patient suffering a cardiac arrest in a hospital in the presence of nurses. As first responders, nurses start emergency treatment and call physicians for help. Incoming physicians have to be included immediately in decision making and delivering treatment. After arriving, physicians have to be accurately informed about the patient's history, current status, and treatments already provided.

Information transmission between medical professionals has mainly been studied in shift handovers as continuity gaps (Cook, Render, & Woods, 2000). Although during regular handovers, groups use multiple strategies to ensure accurate and complete information transmission (Patterson, Roth, Woods, Chow, & Orlando Gomes, 2004), previous studies have found considerable information loss during regular handovers (Bruce & Suserud, 2005; Pothier, Monteiro, Mooktiar, & Shaw, 2005) and even more in emergency situations (Kozer et al., 2002). The situation studied here is different from a regular shift handover, as it occurs under considerable time pressure (Faraj & Xiao, 2006; Marsch, Spychiger, Mueller, & Hunziker, 2002), parallel to ongoing emergency treatment, and with the aim of immediately including the

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joining group member as an active participant. This type of handover has not yet been extensively studied.

Shortcomings in communication are among the most important causes of adverse events in high-reliability organizations, such as aviation (Hackman, 1993; Kanki & Palmer, 1993), nuclear power plants (Roth, 1997; Takano, Sasou, & Yoshimura, 1997), and medicine (Lesar, Briceland, & Stein, 1997). In this literature, inaccurate or incomplete information transmission has been identified as an important issue. For example, a study investigating medication errors found that approximately 20% of the errors were attributed to faulty recording or transmission of information (Ford, Killebrew, Fugitt, Jacobsen & Prystas, 2006). In another study, information transmission was a contributing factor in as many as 43% of incidents in surgeries (Gawande, Zinner, Studdert, & Brennan, 2003).

In aviation, half of the communication-related incidents were related to information transmission, and these incidents had especially serious consequences (Parke, Patankar, & Kanki, 2003). However, many of these studies rely on analyses made after an incident has occurred. They may suffer from hindsight bias, and information transmission is probably only one of several factors contributing to adverse events (Woods, Patterson, & Cook, 2007). This makes it especially important to prospectively and systematically study the potential influences on the quality of information transmission in high-risk settings.

The aim of this study is twofold. First, we assess the accuracy of the information transmitted to nurses or physicians joining an emergency. Second, we test hypotheses about factors that might influence the accuracy of the information transmitted, thus contributing to the understanding of transmission failures. We first present the situation studied, then discuss possible influences on information transfer accuracy, and, finally, present our hypotheses.

The Situation: A Cardiac Arrest

Using a high-fidelity patient simulator, we modeled a scenario after an in-hospital cardiac arrest. This condition requires immediate treatment, which is based on a well-established algorithm (de Latorre, Nolan, Robertson, Chambrelain, & Baskett, 2001). The “patient” suffered a cardiac arrest in the presence of a nurse. This first responding nurse calls two other nurses for help, and they start resuscitation. The nurses page a resident and, later, a senior doctor. Upon joining, the physicians have the responsibility for treatment (Marsch et al., 2002; Marsch, Müller et al., 2004; Tschan et al., 2006). Therefore, it is crucial that they receive reliable information about the patient’s history, current state, and treatment already delivered. While new members join the group, the ongoing treatment cannot be interrupted without high risk of harming the patient, as 1 min of untreated cardiac arrest reduces survival chances by 7% to 10% (von Planta & Osterwalder, 2001).

Influences on Information Transfer Accuracy to Incoming Members in Emergencies

To ensure adequate transmission to incoming group members, information must be (a) encoded and stored, (b) accurately remembered, and (c) accurately communicated. Accuracy of information transmission therefore depends on memory processes (Anderson, 1995). In addition, team processes may influence information transmission.

Age of information. Information is subject to forgetting, which is dependent on time. To be transferred from short-term to long-term memory, information has to be rehearsed. This requires cognitive resources and is more difficult if new information is constantly arriving, as is the case in the situation studied. If the information is generated earlier (and is thus older), it is more likely that it will be forgotten (Baddeley, 1976). We therefore assumed that the likelihood of errors increases with the age of the information (Hypothesis 1).

Attentional focus. If many actions are carried out in parallel and only one person focuses on the information, transmission accuracy depends on this individual. However, if all team members focus their attention on information as it is generated, back-up behavior among group members is possible (Salas, Sims, & Burke, 2005). One could therefore assume that recall accuracy will increase if the group has a common attentional focus during information generation (Argote, Ingram, Levine, & Moreland, 2000).

However, empirical evidence of collective remembering is mixed (Barnier, Sutton, Harris, & Wilson, 2008), with other studies finding a curvilinear effect (Tindale & Sheffey, 2002), inhibiting effects of collaboration on collective remembering (Weldon & Bellinger, 1997), reduced effort with shared responsibility (Weldon & Gargano, 1988), and that groups may leave the "burden of remembering" to members regarded as experts (Hollingshead, 2000).

Those contradictory findings are typically based on laboratory experiments with naive participants performing tasks that are far from the meaningful problems dealt with by experts. For our setting, we propose that a common attentional focus will reduce transmission errors (Hypothesis 2).

Distractors. Distractors (e.g., noise) may divert attention from the information generated and impair encoding and storing (Eysenck, 1976). Previous research has shown that noise impairs the recall of information (Rabbitt, 1968), even in a commonly noisy environment (e.g., operating theaters) and even if the particular noises are well known (Murthy, Malhotra, Bala, & Raghunathan, 1995). In the situation studied, sources of distraction are alarms from the monitor and people talking about other things, given that many acts are carried out in parallel. Meaningful speech that is irrelevant for the task at hand may impair memory performance as much as can simple noise (Hygge, Boman, & Enmarker, 2003). It is likely that noise during information generation impairs storage and recall and diminishes transmission accuracy (Hypothesis 3).

Explicit communication and ease of information retrieval. Ease of information retrieval depends on the way information is encoded. According to transfer-appropriate processing theory, information retrieval is facilitated if the encoding corresponds to the way the information is to be retrieved (Morris, Bransford, & Franks, 1977). For instance, when the information refers to the total number of defibrillations, it should be easiest to retrieve if it has been encoded as a sentence that contains the number of defibrillations (e.g., "This is our third defibrillation."). This encoding allows direct access of the information (direct retrieval strategy; Brown, 1997).

Without transfer-appropriate encoding, each defibrillation is likely to be encoded as a single episode. The number of episodes then has to be recalled by indirect strategies (Brown, 1997), such as recalling each episode and counting the episodes (enumeration) or estimating their frequency using context information (memory assessment; e.g., "We normally defibrillate *X* times within 5 minutes."). The direct retrieval strategy is superior to other strategies (Brown, 1997), and if the events to remember are highly similar, as in our study, even accurate episodic information is less likely to be easily accessible (Menon, 1993), which makes the enumeration strategy especially error prone (Schwarz & Oyserman, 2001). Furthermore, much information in a resuscitation situation is based on actions performed (e.g., chest compressions) and is not acknowledged verbally. In this case, reporting requires memory retrieval based on visual or proprioceptive cues and the subsequent translation into a verbal code, which could impair accurate reporting.

Transfer-appropriate processing theory leads to the prediction that transmission accuracy should be enhanced if group members communicate in a way that supports a direct retrieval strategy, as compared with communication that differs from the way the information must be transmitted (Hypothesis 4a). Furthermore, information that is based on uncommented actions should be particularly difficult to retrieve and therefore more inaccurate (Hypothesis 4b).

METHOD

The study was conducted in the simulation center of the intensive care unit of a university hospital in Switzerland.

Participants

Of the 98 participants, 58 were registered nurses (48 women, 10 men), 20 residents (6 women, 14 men), and 20 senior physicians (1 woman, 19 men). They participated for training purposes and were debriefed after the session. Participants worked in groups composed of 3 nurses, 1 resident, and 1 senior doctor. In two groups, only 2 nurses participated. All participants worked in their professional roles. Assignment to groups was based on the availability of participants. Sessions lasted between 12 and 15 min and were video recorded.

Apparatus

Patient simulator. A high-fidelity human patient simulator was used. It consists of a full-sized manikin. The "patient" talks (through an intercom), it blinks, its pupils react to light, and its chest wall motions can be observed, pulse can be palpated, and heart and lung sounds can be auscultated with a stethoscope. The manikin can be ventilated, and defibrillation is possible by applying controlled electric shocks to restart regular heart rhythms. The simulator displays real-time reactions to therapies administered. The patient was connected to a standard monitor displaying blood pressure, oxygen saturation, and an electrocardiogram. A defibrillator was available.

Medical scenario. The patient was a 62-year-old male transferred to intensive care for postintervention surveillance after percutaneous transluminal coronary angioplasty (PTCA; dilating a heart vein to allow better blood flow). The case history was given to a nurse at bedside. He or she could call two other nurses, and a resident and a senior physician could be paged. The situation unfolded as follows. Initially, the patient was alert. After 2 min of normal heartbeat, episodes of self-limiting ventricular tachycardia (VT; an abnormally rapid heart rhythm) occurred, followed by unlimited ventricular fibrillation (VF; the heart shows rapid but uncoordinated electrical activity and is no longer pumping blood effectively). This represents a cardiac arrest. Without resuscitation, this condition is fatal within minutes. After 3 to 5 min into the scenario, asystole (no measurable heart rhythm) started. Administering epinephrine resulted in the reappearance of VF, which could be converted to normal heartbeat by defibrillation. Treatment of a cardiac arrest follows standardized procedures described by the Advanced Life Support (ALS) algorithm (von Planta & Osterwalder, 2001). All participants were familiar with this algorithm (Marsch, Hunziker, et al., 2004).

Procedure

On arrival, participants were familiarized with the simulator, instructed in the use of instruments and the monitor, and given the opportunity to auscultate and to palpate the pulse. One nurse was randomly selected to be the first responder. The other participants left the room. Participants did not know that a cardiac arrest scenario would be presented.

Initially, the patient declared feeling well, with minor back pain, which he attributed to the hard stretcher. As soon as the self-limiting VT started, the nurse on bedside summoned the colleagues. When the patient's state worsened, the nurses paged the resident and, later, the senior doctor. Thus, there were three occasions of information transmission: (a) to incoming nurses, (b) to the resident, and (c) to the senior doctor.

Measures

According to video recordings and transcripts, all communication and all relevant actions were coded. We proceeded in three steps. First, we identified all information given verbally to the incoming person (information transmission). Second, for each information transmission, we identified all related prior communication and actions (information generation). Third, comparing the content of the information generated and transmitted, we assessed transmission accuracy.

Information transmission. Information transmission was coded as verbal information about the patient (demographics, history, physical state), and treatment provided before the new member entered (e.g., "We administered 1 mg of epinephrine.").

Information generation. For each unit of information transmitted to an incoming person, all thematically related pieces of information generated previously were identified as belonging to the *information generation episode* for this information transmission. For example, the information generation episode for information about medication given to an incoming doctor consisted of (a) verbal communication (e.g., discussion about what to administer) and

(b) actions (e.g., visibly administering medication) that were related to the medication and that occurred before the physician entered. Note that the elements of an information generation episode are not necessarily adjacent in time.

In regard to action and communication units, information can be generated directly, by performing actions or observing others performing them, or by verbal communication.

Action units were coded from a task analysis (Mackenzie, Xiao, & Hors, 2004) based on resuscitation guidelines (de Latorre et al., 2001) and adapted for the current setting (e.g., the guidelines prescribe setting an IV access, which was already established in the simulation). The action units were (a) checking consciousness, (b) checking circulation, (c) measuring blood pressure, (d) executing a precordial thump, (e) cardiac massage, (f) ventilation, (g) defibrillation, and (h) medication. All actions related to one of these categories were coded. This procedure constitutes an action transcript, similar to a transcript of verbal communication.

Communication units were coded with the use of verbs as the main carriers of meaning (Tschan, 1995). In practical terms, this usually amounts to a spoken sentence as unit. Content categories for communication units were the same as used for action units. Communication and action units were coded with regard to characteristics relevant for our hypotheses.

As the basis for calculating age, we coded each information generation episode with regard to its starting point.

Common attentional focus of group members was coded as being present (coded as 1) if all group members looked at the same spot or performed the same task; otherwise, attentional focus not being present, it was coded as zero (0).

To assess noise, we rated the amount of parallel talk or real noise (e.g., alarms) at the time the information was generated on a 3-point scale. We coded low noise (1) when only one information exchange took place and no alarm was present, medium noise (2) when two information exchanges were going on simultaneously or an alarm was sounding during information exchange, and high noise (3) when three or more different information exchanges going on simultaneously (with or without alarm).

To assess *transfer-appropriate encoding*, we determined for each verbal communication unit whether it was explicitly encoded in a way that resembled the way the information would later have to be transmitted. For example, the statement "I'm defibrillating for the third time" was coded as transfer appropriate, whereas statements such as "We should defibrillate" or "Did the defibrillation work?" were not so coded.

Regarding information generation episodes, communication units and action units were coded as part of a given information generation episode when they were thematically related to specific information later transmitted to an incoming member (Futoran et al., 1989).

Characteristics of the information generation episode were calculated as follows: Age of the information was calculated as the time elapsed in seconds between the first unit of the episode and the time the information was transmitted to the incoming person. Overall common attentional focus was calculated as the proportion of common attentional focus during the information generation episode. Noise level was calculated as the mean noise of all units of an information generation episode. The proportion of transfer-appropriate encoding was calculated as the sum of transfer-appropriate statements divided by all communication units of an episode. The proportion of action units is the sum of the action units divided by all units (action and communication) of an episode.

To ensure coding reliability, a coder unaware of the hypotheses double coded15% of the data. Interrater agreement for unitizing, episode building, and all coding categories was high (Cohen's kappa between 0.75 and 1.0).

Coding the accuracy of the information transmitted to incoming member. To assess whether information transmitted to the incoming member was accurate (0) or contained errors (1), we compared each unit of information transmitted with the information contained in the generation episode. For example, if an incoming doctor was informed that four defibrillations had been performed, we counted the number of defibrillations actually performed to assess accuracy. All accuracy assessments were double coded. Interrater agreement was very high (Cohen's kappa = .99).

Analyses

Because many pieces of information were transmitted in each group, the observations are not independent. Multilevel modeling (MLWin 2.0; Hox & Maas, 2001; Jones, 1991; Nezlek, 2003) is the appropriate method for analyzing such hierarchically structured data. Level 1 contains the information episodes and the information transmitted, which are nested in groups (Level 2). Given that the dependent variable (information transmission accuracy) is dichotomous, we performed binomial multilevel analyses (a logistic regression procedure) and used second-order PQL (Penalized Quasi-Likelihood) linearization. Results were transformed and expressed as percentage of errors in information transmission (Rasbash, Steele, Browne, & Posser, 2005). With the exception of noise, zero is a meaningful number for all variables. Therefore, only noise was centered at the grand mean.

Control variables. We controlled for two variables that might affect transmission accuracy: to whom a piece of information was transmitted (nurse, resident, senior doctor) and by whom it was transmitted (nurse, resident).

RESULTS

Descriptive Results

For the 20 groups studied, a total of 2,813 units were coded, consisting of 2,285 communication units and 528 action units. Of 233 information units identified, 32 were omitted from the analyses because there was no observable information generation (i.e., information about the patient was given to the nurse at bedside before video recording started). Analyses are therefore based on 201 information units (M = 10.05 per group, SD = 3.5).

On average, there were 8.33 units (SD = 7.67) per information generation episode. Of those, 1.40 (SD = 1.97) were action units and 6.93 (SD = 6.58) were communication units.

Amount and Content of Inaccurate Information Transmission

Overall, 18% (36 of 201) of the information units transmitted to an incoming member was inaccurate. Of these, 35 units were related to medication or defibrillation, and only one transmission error referred to other content. Thus, errors in transmission mainly occurred if numbers had to be transmitted, namely, those referring to dosage and frequency of medication or defibrillation strength and frequency.

Predicting Information Transmission Inaccuracy

Level 1 bivariate correlations among all study variables are presented in Table 1. Of the control variables, source of information transmission was not significant (B = .391, SE = .401).

With regard to the recipient, transmitting information to the senior doctor was significant. Therefore, in the final model, we included a dummy variable representing whether the information was transmitted to the senior doctor.

To test our hypotheses, we entered all five predictor variables simultaneously, thus controlling them for each other. Results are summarized in Table 2. In logistic regression, betas are not easily interpretable (Rasbash et al., 2005). To allow better understanding, in Figures 1 and 2, we illustrate the results for the significant predictors in terms of percentages of predicted inaccuracy (controlling for all other variables in the equation) for the 25th and the 75th percentile of the predictor.

Hypothesis 1, predicting that older information lowers transmission accuracy, was supported. In terms of probabilities, this finding implies that errors in information transmission are estimated at 22% if the duration between generation and transmission is at the 75th percentile, as compared with the baseline of 18%. By contrast, if time elapsed since information generation is at the 25th percentile, the estimated error rate drops to 13% (Figure 1).

Hypothesis 2 suggested a relationship between common attentional focus of the group members during information generation and information transmission accuracy. The data did not support this hypothesis. Hypothesis 3 stated that more noise during information generation lowers transmission accuracy. This was not supported by the data.

Hypothesis 4a stated that transfer-appropriate verbalization during the generation phase would enhance transmission accuracy. This was supported by the data. To illustrate this effect,

TABLE 1: Information Transmission Episodes: Descriptive Statistics and Level 1 Correlations

Variable	Count		1	2	3	4	5	6	7	8	9
Control variables											
1. Information transmission in Phase 1 (only nurses present)[a]	15		—								
2. Information transmission in Phase 2 (to resident)[a]	55		NA	—							
3. Information transmission in Phase 3 (to senior doctor)[a]	131		NA	NA							
4. Information transmitted to senior physician by resident (by nurses)[a]	84(47)		NA	NA	NA	—					
	M	*SD*									
Predictor variables											
5. Duration of information generation phase (in seconds)	180.34	133.38	–.275**	–.358*	.487**	.446**	—				
6. Common focus during information generation[b]	.46	.50	.157*	.218*	–.282**	–.179**	–.258*	—			
7. Noise during generation (mean)	1.89	.54	–.237**	–.280**	.391**	.232**	.076	–.236**	—		
8. Proportion of explicit communication on all communication in episode	.42	.38	.079	.107	–.144*	–.080	–.155*	.223**	–.113	—	
9. Proportion of action units in episode	.15	.20	–.031	.152*	–.125	–.088	.080	–.114	–.028	–.513**	—
Dependent variable											
10. Inaccurate information transmission[c]	.18	.38	–.133	–.112	.178*	.070	.246*	–.128	.014	–.401**	.202**

Note. Based on 201 complete episodes of 20 groups. NA = does not apply.
[a]Correlations are based on the dummy coded variables.
[b]Dummy coded; 1 = common focus.
[c]Dummy coded; 1 = inaccurate transmission.
$*p < .05$. $**p < .01$.

TABLE 2: Predicting Inaccuracy of Information Transmission

Variable	*B*	*SE*
Null model		
Intercept	–1.522*	0.183
Model entering control variables and all predictors		
Intercept	–1.743*	0.749
Time of information transmission (1 = transmitted to senior doctor)	0.006	0.668
Duration of information generation phase (in seconds) (Hypothesis 1)	0.005*	0.002
Common attentional focus of the group during information generation (Hypothesis 2)	0.235	0.503
Noise present during generation (grand mean centered) (Hypothesis 3)	–0.153	0.543
Proportion of explicit communication indicating transfer-appropriate encoding (Hypothesis 4a)	–4.928*	1.152
Proportion of action units of all units of episode (Hypothesis 4b)	2.112	1.290

Note. Bimomial multilevel model. Level 1 = 201 information transmission episodes; Level 2 = 20 groups. Significance levels are based on the Wald test, as suggested by Rasbash, Steele, Browne, and Posser (2005).
*$p < .05$.

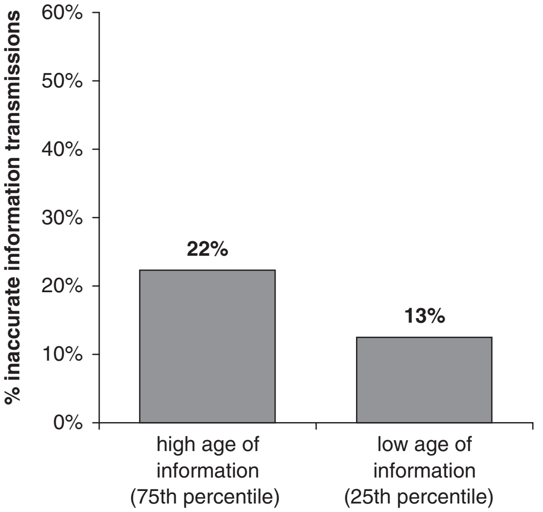

Figure 1. Proportion of inaccurate information transmitted to incoming professionals for high and low age of information.

Figure 2 shows that if the proportion of transfer-appropriate encoding of all communication is on the 75th percentile, inaccurate information transmission drops to 3%, and if it is on the 25th percentile, errors in information transmission are estimated to be 52%. Hypothesis 4b stated that a higher proportion of actions, as compared with communication, within a generation episode would impair transmission accuracy. This hypothesis was not supported by the data.

DISCUSSION

Our goal was to assess the accuracy of information transmitted to incoming professionals on the basis of how that information was generated. It is difficult to compare the error rate of 18% with previous findings, as most of the previous studies investigated information transmission problems in relation to incidents. However, one can assume that transmission errors will increase the risk for adverse events but not automatically lead to negative consequences (Patterson et al., 2004). Note that we assessed the accuracy of information actually transmitted and did not include omissions. Thus, the error rate found likely underestimates transmission problems in such situations.

The two factors (age of information and transfer-appropriate encoding) that predicted information transmission accuracy in this study appear clearly related to memory processes, particularly to the ease of encoding. It is well known that forgetting occurs over time (Anderson, 1995; Baddeley, 1976). However, the time frame in this study was very short, as the information transmitted was on average about 3 min old. The decline in participants' ability to correctly recall information therefore happened very quickly. This result may have also depended on the type of information transmitted. Recall that it was mostly information related to either counting of repeated behavior or numerical values that was transmitted incorrectly. Such information

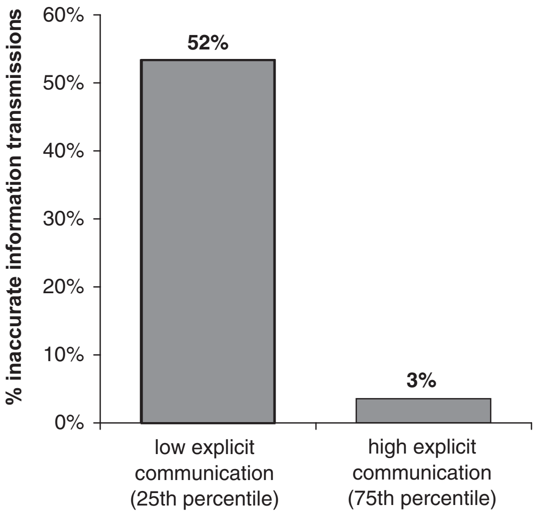

Figure 2. Proportion of inaccurate information transmitted to incoming professionals for low and high proportion of explicit (transfer-appropriate) communication during information generation.

represents a high demand on working memory and is therefore especially error prone (cf. Wickens & Hollands, 2000).

Previous research has shown that it is particularly difficult to remember how many repeated isolated events have happened (Schwarz & Oyserman, 2001). To report such events, people tend to reconstruct the number of events rather than actually remember them, which leads to distortions (Brown, 1997).

The communication of statements that allow transfer-appropriate encoding did have a strong association with transmission accuracy, supporting transfer-appropriate processing theory (Morris et al., 1977). The communication of statements facilitates a direct retrieval strategy, which has been shown to be superior (Brown, 1997). Our study indicates that transfer-appropriate encoding is important not only in individual but also in group recall, pointing to the need to study encoding processes in group recall in more detail.

Noise was not related to transmission accuracy, contradicting previous research. In this study, the main distractors were parallel talk or alarms and were related to the task and thus may have been less distracting. In addition, medical professionals may be used to working in noisy environments and may have developed strategies to focus on their immediate task (Wickens & Hollands, 2000), such as ignoring ongoing alarms (Xiao, Seagull, Nieves-Khouw, Barcazk, & Perkins, 2004).

Common attentional focus was not related to information transmission accuracy. This finding corresponds to other studies that have postulated processes such as cognitive loafing (Weldon & Gargano, 1988) or social loafing (Comer, 1995) or effects of shared responsibility as possible explanations. It is also conceivable that medical professionals, accustomed to parallel work, may have developed strategies to register information that is not in their attentional focus. Clearly, this topic needs more research.

Recommendations

There are three practical recommendations. In a general vein, nurses and physicians joining an ongoing emergency should be aware that some of the information transmitted—most notably, quantitative information—may be inaccurate. They should adapt their actions to this possibility.

Second, technical solutions may support information retrieval, such as defibrillators that can be programmed to automatically record and display the number of defibrillations delivered (Woods et al., 2007). This is in line with the recommendation to avoid reliance on memory by the Committee on Quality of Health Care (Kohn, Corrigan, & Donaldson, 2000, p. 170).

Third, one can train medical professionals to engage in more explicit communication that entails transfer-appropriate encoding, such as explicitly counting out loud the defibrillations during resuscitation. However, people may feel awkward doing this, as such explicit communication contradicts the general communication rule to avoid redundancy (Grice, 1975). Such changes in communication behavior thus require training (e.g., Flin, O'Connor, & Mearns, 2002; Hopkin, 1995).

Limitations and Strengths

We had a limited focus in this study and investigated a very specific question. Thus, this study is not suited to assess adverse events, as such an assessment would require a wider framework, including social and organizational aspects (Woods et al., 2007). Another limitation of the study is the small sample of 20 groups, because it restricts statistical power. Also, given that all groups were confronted with a cardiac arrest, generalizability to different tasks is unclear. Furthermore, there was limited standardization of the situation, and the amount of information transferred to incoming members varied.

However, these limitations are a consequence of the realistic situation studied, which is one of the strengths of the study. Another strength is that information transmission accuracy and the influencing factors were assessed on the basis of behavioral observation. In contrast, many other studies investigating information transmission have relied on memory reconstruction and thus may suffer from hindsight biases (Woods & Cook, 2002). This study also contributes to theoretical development in the domain of collective recall in showing that the superiority of transfer-appropriate encoding holds for recall not only by individuals but also in groups.

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