Development of a Veterinary Surgical Checklist

Aviation and human health care checklists notwithstanding, a checklist for animal surgery requires its own distinct development process.

By Anne Collins McLaughlin, Jessica Ward, & Bruce W. Keene

FEATURE AT A GLANCE:
We describe a new surgical checklist for veterinary cardiologists based on the literature and the application of human factors design. The checklist was developed and iterated with subject-matter experts and was implemented for 4 months, during which use of the checklist was monitored, feedback was gathered, and a final survey was distributed to assess subjective experiences. Although developed for the cardiology team, the checklist also affected the anesthesia team by requiring information and responses to be transmitted across teams. Interviews, subjective reports, and observations pointed to the fact that the checklist engendered communication, particularly by requiring the thoughts and expectations of team members to be stated explicitly.

KEYWORDS:
teams, teamwork, education and training, simulation, surgical procedure, health care, work systems, macroergonomics, product design, design methods, safety, human error, task analysis, Big 5 model, theory of mind

The popularity of checklists in medicine has skyrocketed in the past decade, mostly because of (a) the success of the World Health Organization (WHO) surgical checklist (Haynes et al., 2009), (b) media coverage of the work of Peter Provonost (Provonost et al., 2006), and (c) *The New York Times* bestseller *The Checklist Manifesto* by Atul Gawande (2009).

Many agree that it is past time for checklists to be applied to medicine as they were applied to aviation, (e.g., Weiser et al, 2010) although medical checklists have faced similar challenges that aviation checklists faced long ago, such as resistance to change and hierarchical team culture (Gawande, 2009). Also, making a good checklist for a medical team or teams is a long and somewhat idiosyncratic process: At least currently, checklists are not easily transferred between groups, hospitals, or types of care (WHO, 2009).

This challenge is possibly why the veterinary community has been particularly underserved when it comes to checklist development (McMillian, 2014). Our review of the literature found very few checklists for veterinary surgical procedures that approximated the WHO surgical safety checklist (e.g., Gasson & Wager, 2013), despite the arguably higher complexity of veterinarians' jobs, given the variety of animal species and sizes.

A close collaboration with faculty at the North Carolina State College of Veterinary Medicine offered the chance to introduce a surgical checklist for its most common cardiac catheterization procedures. These procedures involved at least two teams, cardiology and anesthesiology, and shared the commonalities of requiring general anesthesia and accessing the patient's heart via insertion of a catheter through an artery or vein. The three most common procedures were balloon valvuloplasty (BV), wherein a balloon is inflated inside the heart to open a stenotic valve; patent ductus arteriosus occlusion (PDA), wherein a heart defect is corrected with an implanted device; and pacemaker implantation. The goal was to introduce a general surgical checklist that covered the three procedures.

Our results include a specification of the procedure used to create the checklist, our methods of evaluation, and our supposition that one of the main benefits of a checklist is to reduce egocentrism and increase theory of mind between teams and team members (Apperly, 2012; Savitsky, Keysar, Epley, Carter, & Swanson, 2011).

PROCEDURE

We modeled the development and testing of the checklist on the WHO literature (e.g., it must be focused, brief, actionable, verbal, collaborative, tested, and integrated into the specific team and environment; WHO, 2009) combined with a team focus from the "Big 5" model of teamwork (Salas, Sims, & Burke, 2005). We also began with the intent to design the checklist via good human factors design principles, taking into account the perceptual, cognitive, and motor needs of the checklist users.

The first step was to perform a checklist needs analysis through an analysis of the surgical procedures to be performed, identification of the goals of the checklist, and assessment of the team cultures for readiness to accept a checklist. The checklist needs analysis was created by combining the

10. Position balloon			Skill required			Potential Errors
Step		Worker	Motor	Perceptual	Cognitive	
10.1	**Identify PA Annulus**					
10.1.1	Add color	Vet	low	high	high	
10.1.2	Capture images	Tech	medium	high	high	Sub-optimal screenshot recorded
10.1.3	Identify best image	Vet	low	high	medium	Mis-identification
10.2	**Measure PA Annulus**	Tech				
10.2.1	Bring up best image	Tech	low	high	medium	
10.2.2	Confirm choice with Vet(s)	Tech	low	low	low	
10.2.2.1	Vet looks at visual to affirm	Vet	low	high	high	Often lacks comparison to other images
10.2.3	Select measurement tool	Tech	low	low	medium	Difficult to differentiate icon
10.2.4	Change measurement to mm	Tech	low	low	high	Default is always incorrect (French)
10.2.5	Select 30mm	Tech	low	low	high	Typo possible
10.2.6	Measure 30mm against ruler	Tech	high	high	low	Accuracy depends on movement accuracy of tech
10.2.7	Click calibrate button	Tech	low	low	low	
10.2.8	Click to identify PA Annulus	Tech	high	high	medium	Accuracy depends on movement accuracy of tech
10.2.9	Confirm action via visual with Vet(s)	Tech	low	low	low	Dialoge occurs via intercom
10.2.9.1	Vet looks at visual to affirm	Vet	low	high	high	Often an interruption
10.2.10	Report measurement value	Tech	low	low	low	Report occurs via intercom
10.3	**Calculate balloon size**	Vet				
10.3.1	Select balloon	Vet	low	low	medium	Done as mental calculation by Vet(s)
10.4	**Insert balloon along lead wire**	Vet				
10.4.1	Position balloon	Vet	high	high	medium	Requires team hand-eye coordination with cath
10.4.2	Inflate balloon	Vet	medium	low	low	Requires team hand-eye coordination with cath

Figure 1. Sample task analysis from a portion of the balloon valvuloplasty procedure. Number of steps and potential errors informed checklist needs analysis.

findings from the task analyses and interviews with stakeholders.

Ten procedures were observed for the task analyses: seven BVs, two PDAs, and one pacemaker implantation (Figure 1). General findings were that these procedures occurred around one to two times per week, rarely after hours. If a procedure was performed after hours, it was typically for an animal that was in a critical state and could not wait for a scheduled appointment. Thus, the population of animals treated after hours appeared to be those under emergency circumstances, whereas those treated during normal hours tended to be more stable. Other observations were that staff were more limited after hours and team members had to fill roles other than their own to perform after-hours procedures.

Three findings from the task analysis directly informed the checklist. First, communication between teams occurs before, during, and after the procedures, but it was challenging to coordinate individual schedules. Second, procedures spanned three rooms: one for anesthesia preparation, the surgical theater, and an adjoining room with computer equipment that controlled visual displays for the electrocardiogram, pressure monitoring, blood oxygen, fluoroscopy, and ultrasound (Figure 2). Third, equipment was prepared ahead of time, but size estimates for implants and other equipment could change during the procedure, necessitating additional retrieval.

Procedures followed a general flow but were highly dynamic depending on the stability or needs of the patient, those performing the task (resident vs. faculty), and the length of time required to perform difficult procedural steps.

From the task analysis, we concluded that the most appropriate type of checklist would be "do verify," whereby the team pauses for checklist items but performs the task without being prompted step by step. The do-verify checklist applies best to highly trained teams performing complex tasks without clear demarcation between steps; both these attributes emerged in the task analyses. The other type of checklist is known as the "to-do" checklist and is more appropriate for tasks that require absolute protocol adherence to each step, such as hand hygiene (Drews, 2013).

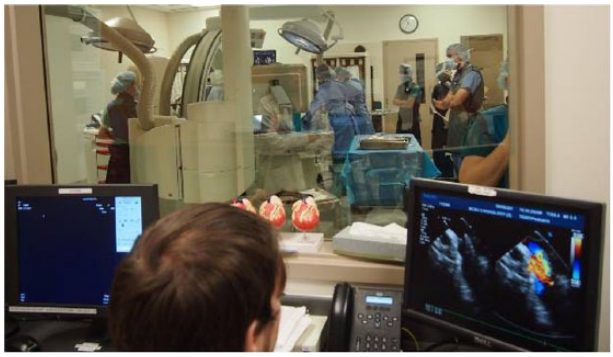

Figure 2. The surgical theater where cardiac catheterization procedures are performed, with the viewing/computer equipment room adjoined.

We then conducted seven in-person interviews with representatives of all roles in the surgical and anesthesia teams, including technicians, faculty, and residents. Each person answered similar questions, and we asked more in-depth follow-up questions as they answered. These follow-ups were often specific to respondents' perceived needs regarding a procedure. For example, we asked, "Before the start of the procedure, what information do you need from each team member?" and "What information tends to be scarce, unavailable, or missing related to a pacemaker procedure?" These interviews were transcribed and reviewed for themes and information that could inform the checklist. We also showed examples of other medical checklists and elicited feedback on what applied or did not apply to the participants'

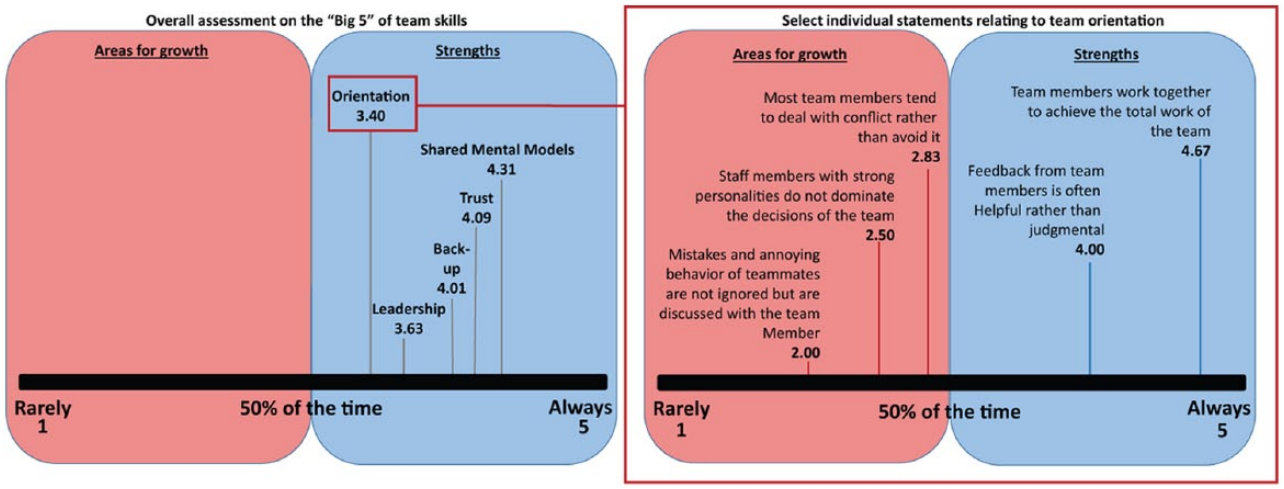

Figure 3. Left: Overall assessment on the "Big 5" of team skills. Right: Breakdown of individual statements relating to team orientation.

work. There were no prior examples of veterinary cardiac catheterization checklists.

Interviewees also completed the Nursing Teamwork Survey (Kalisch, Lee, & Salas, 2012) based on the Big 5 model of necessary team skills: communication, briefing, backup behavior, mutual performance monitoring, team leadership, decision making, task-related assertiveness, team adaptability, and shared situation awareness (Salas et al., 2005). The survey was adapted to be more general than nurse specific, with statements such as "Feedback from team members is often helpful rather than judgmental" and "My team readily engages in changes in order to make improvements and new methods of practice." Respondents selected a rating on a Likert scale from *rarely* to *always*.

General findings were that the teams were highly functional on these skills; all five skills were rated higher than 50% of the time (Figure 3). Some individual statements received lower estimations, such as "Staff members with strong personalities do not dominate the decisions of the team" and "Mistakes and annoying behavior of teammates are not ignored but are discussed with the team member."

From the task analysis, interviews, and surveys, we concluded that the checklist should focus on eliciting discussion between and within teams, particularly for often-assumed information. In other words, one of the main benefits a checklist could bring would be to establish accurate *theory of mind* between team members. Some checklist items did relate to steps that might be overlooked, such as administration of antibiotics, but most items were created to engender discussion.

We disseminated the general findings from discussions with subject matter experts (faculty anesthesiologists and cardiologists) and interviews with all staff through a presentation to the cardiology and anesthesiology teams. For many, this presentation was their first introduction to the checklist, and time was reserved at the end of the presentation for feedback and answering questions. The 30-min presentation covered a brief overview of the success of checklists in medicine, the current checklist initiative with goals and measures, a summary of findings from interviews and surveys, and the draft checklist design. At the end of the presentation, we outlined the next steps in deploying the checklist, including which procedures would involve the checklist and the expectation that all teams would participate in using it.

In the presentation, we also noted that the checklist would be a do-verify checklist, not a to-do list of every possible action. We wanted to communicate that the checklist was not intended to give participants a task list but was to make steps in the procedure more explicit and conscious, with empowered inter- and intra-team communication. For example, the checklist calls for the cardiologist to review, out loud to the teams, any critical events or unexpected steps he or she anticipates and the expected duration of the operation. That communication provides insight into the expected complexity and informs the anesthesia team of what to expect during the procedure.

In sum, the goals of the checklist were, first, to increase task-related communication both between and within the surgical and anesthesia teams prior to the procedure (Lingard et al., 2005) and, second, to capture the subtasks in the procedure that were most likely to be forgotten or that required a shared understanding among team members. The communication objectives were accomplished in three ways: by requiring explicit introductions of team members and their roles, through listing steps that may be considered and accepted or dismissed by a team member without voicing (e.g., whether an "A-line" [arterial line] was necessary), and by prompting vocalization of team members' expectations for the procedure, which primed possible steps and equipment needs in all team members.

The presentation to the two teams was the start of creating a checklist culture. At the recommendation of the WHO checklist implementation starter kit (WHO, 2009), we also created campaign materials to prime team members for the checklist. These materials included buttons and flyers with

Figure 4. Checklist campaign materials developed for the initial use and evaluation of the checklist.

brief facts about checklist efficacy or other communication-related themes (Figure 4).

FORMATIVE EVALUATION

The checklist (Figure 5) was introduced for cardiac catheterization procedures at the North Carolina State College of Veterinary Medicine in January 2015. Procedures were attended by research assistants who observed use (or nonuse) of the checklist, noted physical locations the checklist was moved to or used in, and checked with all available team members after the procedure for their opinions on the checklist. We also elicited feedback on the checklist via e-mail from any team member. This process resulted in minor iterations of language used (*hypotension* vs. *hypertension*) and the addition of a particular step ("A-line discussed"). We continued to observe checklist use during procedures through April 2015, at which point we developed a survey for summative evaluation of the checklist.

SUMMATIVE EVALUATION

We developed a survey to assess the ease of use, desirability, and subjective impact of the checklist on all team members. From 23 potential team members, we received 13 responses. Free-response questions included the following:

- What did you perceive as the biggest positive change brought about by the checklist?
- What did you perceive as the biggest undesirable change brought about by the checklist?
- Can you describe any time(s) the checklist prompted an action that would not have taken place without the checklist?
- Please describe any improvements you would like to make to the checklist. This can be anything from adding/subtracting steps to changing the font or other cosmetic changes.

In general, most positive comments were related to team communication. Some examples follow.

- "Knowing names of team members and feeling more connected as a team, which made it even more comfortable to ask some people questions."
- "Introductions of all team members in the room and improving anes[thesia]-cardio[logy] discussions. Review of anticipated complications."
- "The A-line discussion is very helpful as well as the recovery drug discussion. It is nice to make sure we are all on the same page."
- "Better discussion of what actions steps to take in case of hypotension and post operative sedation protocols."

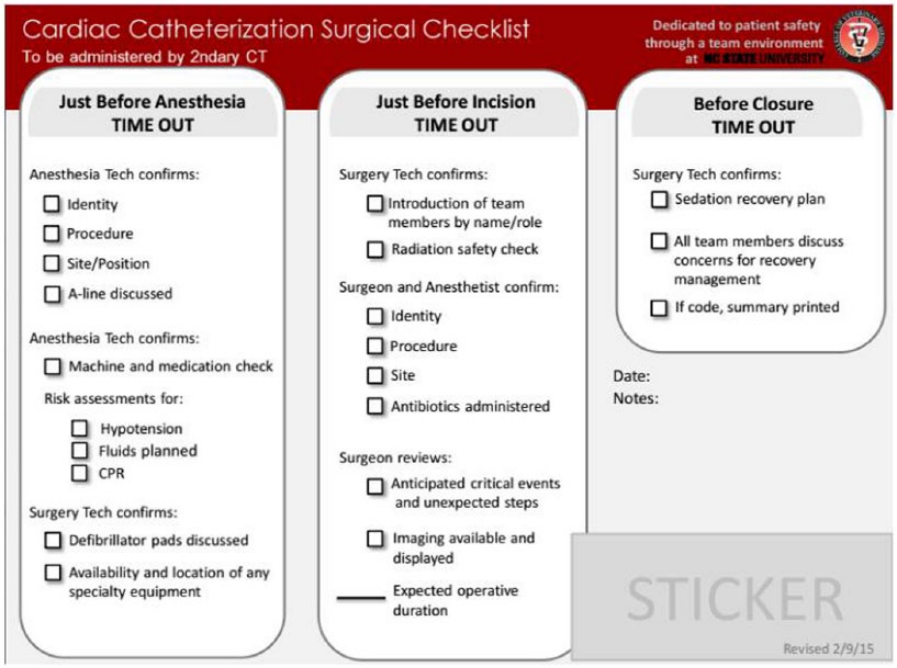

Figure 5. The final iteration of the checklist as implemented in the operating room. Human factors design principles were followed for font size, spacing, language simplicity, and physical use. Roles for discussion and confirmation are clearly specified with the explicit vocalizations of key information.

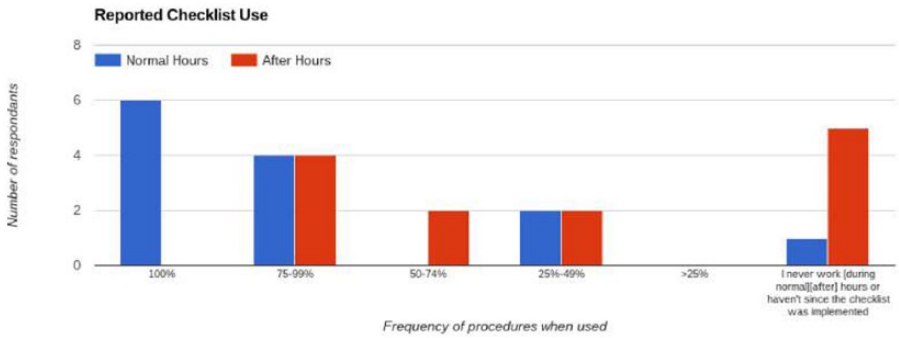

Figure 6. Reported checklist use from respondents to summative evaluation survey. During normal hours, most reported over 75% use, with less consistent use after hours.

- "On several procedures I thought [a step] would have been too time consuming to try, but cardio was very happy to have the [step performed] and wanted me to try for a reasonable amount of time."
- "Better idea of cardiology's specific concerns for the patient. Better idea of anesthesia's specific concerns for the patient."

Fewer comments suggested the checklist prompted a forgotten action:

- "Checking the fluoroscopy equipment ahead of time can be easily forgotten and was remembered due to checklist."
- "Needed equipment wasn't in correct position."
- "Although there is a presurgical form that requests administration of perioperative antibiotics, this is sometimes delayed when the anesthesia team is concerned about other issues. The checklist has helped to confirm the appropriate timing of antibiotics in all cases."

Observations by research assistants and data from the summative evaluation demonstrated that checklist steps were rarely skipped, but on the occasions they were, the reasons given were that those procedures occurred after hours when no surgical tech was present to officiate the checklist or that the last steps "before closure" were most likely to be skipped because the teams have a perception of being finished.

After-hours procedures were the most problematic, with reports that the checklist was never used 100% of the time (Figure 6). As a comparison, most respondents said the checklist was used 100% of the time during normal hours. In addition to the responses given in the summative evaluation

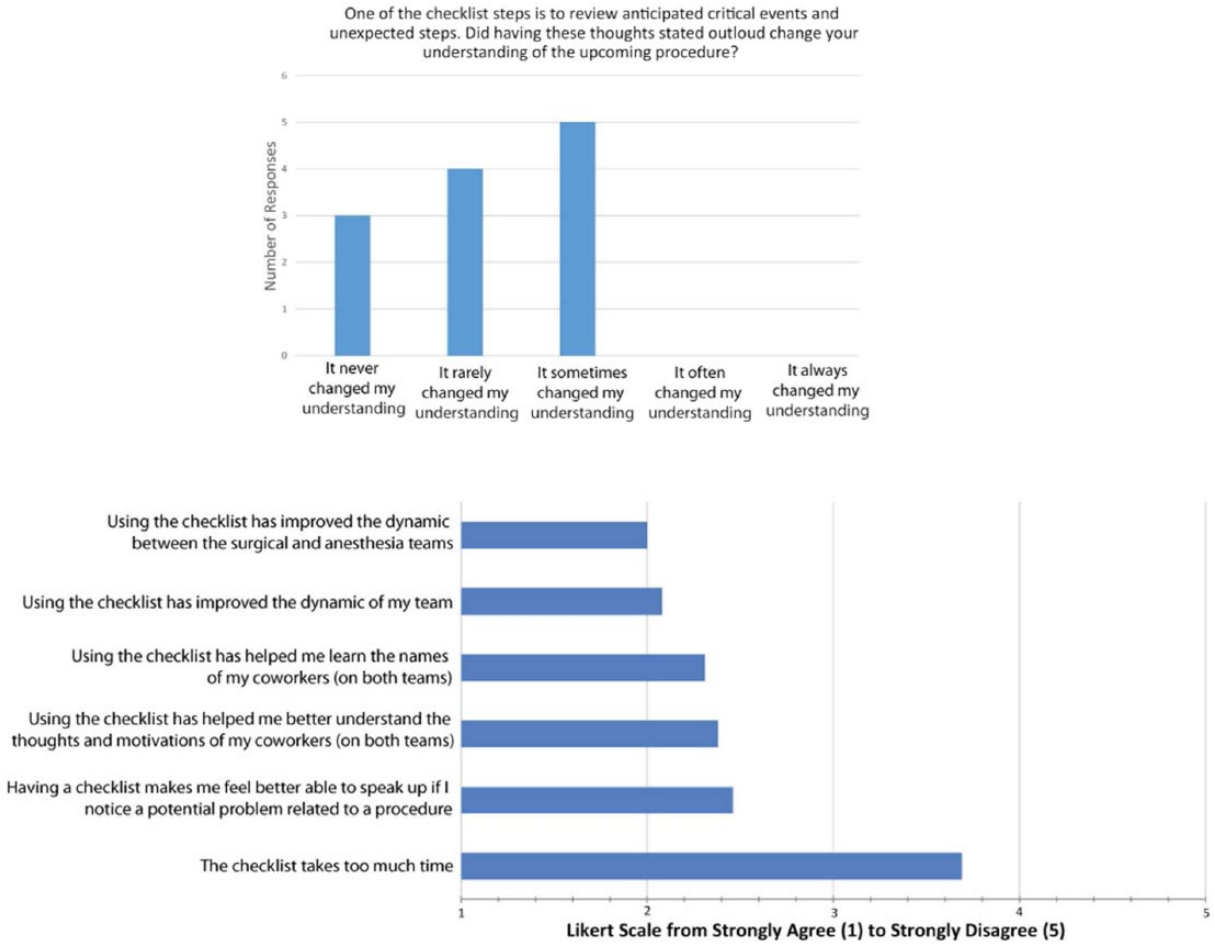

Figure 7. Frequency of responses to question involving changed understanding and mean agreement to statements on a Likert scale from 1 to 5 (*strongly agree* to *strongly disagree*). *N* = 13.

survey, we examined a sample of the actual checklists used throughout and found that only one step was skipped across eight procedures (176 possible steps).

We included several communication-specific questions in the summative evaluation (Figure 7).

DISCUSSION

We concluded that the checklist implementation and use was successful. Subjective reports were positive, with agreement that the checklist promoted teamwork and communication. Our discussion centers on why we believed the checklist was effective.

Although checklists are useful in prompting action and likely forgotten steps, we found that forgetting steps in a procedure was a rare occurrence for highly trained teams working together on well-known procedures. The one instance mentioned by a few team members was the administration of antibiotics prior to the procedure – the checklist was reported to catch the lack of administration a few times during the evaluation period. Such was the case even in a teaching setting with fairly frequent rotation of team members performing most of the tasks. Thus, in addition to the minor role of prompting particular actions, we concluded that the power of the checklist comes from the communication it engendered between and within teams.

Of the teamwork skills defined by Salas et al. (2005), communication was key, and several other skills were related to communication: briefing, backup behavior, and shared situation awareness. The checklist forced explicit vocalization of team members' thoughts and expectations, as when the cardiologist reviewed "anticipated critical events and unexpected steps" or "all team members discuss concerns for recovery management." In the evaluation, we received the most comments regarding this attribute of the checklist. To explain why the checklist improved these discussions, we turn to the literature on adult theory of mind and the tendency toward egocentrism in collaborative tasks.

It is well known that children develop the ability to distinguish another person's thoughts from their own and eventually are able to understand that others have different information, motivation, or emotions. The inability to do this is called *egocentrism*. However, what is not as well known is that adults lack a perfect understanding of another's knowledge and perspective (Nickerson, 1999).

For example, adults trying to communicate spatial location to another person who cannot see the same scene have trouble incorporating the other person's viewpoint when considering their own (Keysar, Lin, & Barr, 2003). When tapping a tune, people overestimate the likelihood that a listener can tell what they are tapping – they are unable to ignore their own knowledge (Apperly, 2012; Newton, 1990). Further, people who are close to one another make more of these assumptions and errors than do strangers (Savitsky et al., 2011), meaning that close-knit teams are likely susceptible to assumptions of shared knowledge. Finally, performing communication tasks when it is important for the listener to take the perspective of the speaker is cognitively demanding (Bernstein, Thornton, & Sommerville, 2011; Epley, Keysar, Van Boven, & Gilovich, 2004), and when in a demanding scenario, no resources remain for perspective taking.

Thus, it appears likely that it is easy for team members to assume that their expectations for possible complications or equipment needs in the procedure are known to those in other roles. Explicitly stating their thoughts means that this knowledge is indeed shared and all team members are primed for events they might not have themselves expected. Also, explicitly stating thoughts reduces the need for other team members to spend cognitive resources trying to apply theory of mind to the speaker.

A last contribution of the checklist was for the skill of task-related assertiveness. Having the names and roles of each team member primed before the procedure began was mentioned most often as a benefit; one respondent reported liking "knowing names of team members and feeling more connected as a team, which made it even more comfortable to ask some people questions." Survey respondents agreed that "having a checklist makes me feel better able to speak up if I notice a potential problem." The benefit of this checklist item may have been especially high in this educational environment, where performance is evaluated. As one participant put it,

> As a resident in training, fear of disapproval/judgment by my superiors can be a barrier to question-asking and effective communication (i.e., I might be afraid to constantly ask [the faculty member] what he is doing/thinking during a procedure because I don't want to appear uninformed).

The checklist assists in this aspect of complex cognitive tasks by making information explicit and forcing all participants to verbalize their thoughts.

FUTURE DIRECTIONS

One of the issues with development of a medical checklist is that checklists are idiosyncratic and need to be tailored to the team(s) and the environment (WHO, 2009, n.d.). Rarely, if ever, are enough people involved in a single checklist to provide stable quantitative data on their subjective evaluation. We would like to see an empirical test of the idea that egocentric communication is significantly reduced in teams by using a checklist. However, this test would need to take place over either a long period , in a facility that performs many procedures per week, or across multiple facilities in a randomized controlled trial.

WHAT IS THE "BIG 5" MODEL OF TEAMWORK?

The Big 5 model of teamwork was created by Salas, Sims, and Burke (2005) to identify the components of teamwork and their interactions. The main purpose of the model was to bring together agreed-upon literature of team interaction into a manageable model that provides recommendations and assessment methods for team performance. These components included team leadership, mutual performance monitoring, backup behavior, adaptability, and team orientation.

Each component has a definition (e.g., mutual performance monitoring is "the ability to develop common understandings of the team environment and apply appropriate task strategies to accurately monitor teammate performance"; Salas et al., 2005, p. 560) and behavioral markers to assess the quality of the component in a particular team. For example, one behavioral marker for adaptability is that a team or team member can "identify cues that a change has occurred, assign meaning to that change, and develop a new plan to deal with the changes" (Salas et al., 2005, p. 560). Between the components are coordinating mechanisms (such as "mutual trust" and "closed-loop communication"), which also have behavioral markers (such as "following up with team members to ensure message was received"; Salas et al., 2005, p. 561). All of these components and coordinating mechanisms are evidenced based, with primary sources informing each.

Recent applications of the Big 5 model include teaching online teamwork through visualizations of the model (Kay, Maisonneuve, Yacef, & Reimann, 2006) and in modeling the teamwork required to supervise multiple robots (Gao, Cummings, & Solovey, 2014). There are clear future directions in the use of this model for checklist research, as surgical checklists are used by teams that need cohesion. It would also be beneficial to study how checklist use that contains items encouraging theory of mind affects the mechanisms in the Big 5, such as shared mental models and mutual trust.

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