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An evidence based framework for the Temporal Observational Analysis of Teamwork in healthcare settings

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ABSTRACT

Objective: Effective teamwork is critical to patient safety across multiple healthcare settings. However, current observational tools assessing teamwork performance tend to be developed for specific settings or tasks and do not capture temporal features of interaction. This study aimed to develop a valid and reliable observational teamwork behaviour framework, which is based on healthcare practice, applicable across a variety of healthcare contexts and can be used to capture temporal team dynamics.

Methods: Team interactions were audio-visually recorded during routine simulation training at two large clinical education centres specialising in physical and mental healthcare. The framework was based on theoretical models of teamwork and was developed in three steps: 1-micro analysis of verbal and nonverbal behaviour during recorded scenarios (n = 20); 2-iterative test and refine cycles; 3-final behavioural framework applied to a cohort of acute emergency scenarios (n = 9) by two raters to assess inter-rater agreement.

Results: The framework contains twenty-three specific verbal and nonverbal behaviours that can be identified during observations. Behaviours are grouped conceptually based on their function resulting in thirteen behavioural functions, which cluster into five overarching teamwork domains. Inter-rater agreement was excellent (Cohen's Kappa = .84, SE = 0.03).

Conclusion: We present a valid and reliable behavioural framework, grounded in teamwork theory and empirical observations of clinical team behaviour. This framework enables analysis of the nuances and temporal features of clinical practice in depth and across a wide range of clinical contexts and settings. Use of this framework will advance our understanding of teamworking in healthcare.

1. Introduction

Healthcare provision relies on multiple professionals, from different healthcare disciplines, working together towards the common goal of patient management and treatment. Such coordinated efforts require effective teamwork, which is a critical determinant of safe patient care (Manser, 2009). However, interprofessional teamwork may be difficult to achieve in practice for a variety of reasons including: cultural and educational differences between professions, perceived and actual inter-professional hierarchies, staff attitudes and perceptions of inter-professional working (Weller et al., 2014; Hall, 2005; Liberati et al., 2016) and the transient and episodic nature of teams in clinical settings (Chesluk et al., 2015). Multi-team systems of care delivery greatly increase the necessity for co-ordination and communication (O'Neill and Salas, 2017). Although some healthcare teams such as general practice may have stable team structures, many areas of healthcare, particularly hospital settings, have a wide variety of team structures, including those without stable membership or with rapid turnover (Chesluk et al., 2015). It is unclear how applicable traditional theories of effective teamworking (e.g. Salas' Big Five (Salas et al., 2005)) are in this environment or how much they reflect the realities of current work practices (O'Neill and Salas, 2017). In this study we report the development of a behavioural framework for documenting teamwork behaviours that are applicable across a range of clinical scenarios, healthcare settings and professional groups. This framework represents a set of observable verbal and nonverbal teamwork behaviours that have

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been identified during interprofessional clinical scenarios.

A number of teamwork performance tools for use in healthcare already exist and these have been consolidated in a recent review (Marlow et al., 2018). The majority of these are designed for a specific clinical setting, such as operating room settings (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009; Fletcher et al., 2003; Lyk-Jensen et al., 2014) or emergency care settings (Cooper et al., 2010) and for use with specific professional groups (e.g. anaesthetists (Fletcher et al., 2003) or surgeons (Yule et al., 2006)). A commonality across all such performance tools is that they involve a behavioural rating system (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009; Fletcher et al., 2003; Lyk-Jensen et al., 2014; Cooper et al., 2010; Frankel et al., 2007; Weller et al., 2011; Taylor et al., 2012), where an observer makes a judgement about how well each behaviour was performed, providing a final summative score for the observed interaction as a whole. Such tools can be used for benchmarking teamwork performance within a specific context and providing summative scores to specific professional groups engaged in predefined tasks. However, clinical interactions, as with all social encounters, are complex and dynamic. Behaviours of interacting partners are mutually dependent; team members respond to the actions and communication of others. The tools described above do not consider this complex interdependence, or the temporal dynamics of a clinical encounter. They are therefore limited in their ability to develop our understanding of how clinical teamwork unfolds temporally and whether and how patterns of teamworking are related to team outcomes. They are also not applicable beyond their pre-defined target professions and clinical settings.

An exception is the behavioural framework developed by Manser and colleagues (Manser et al., 2008) based on ethnographic analysis of surgical settings, which we first considered as the basis for our own empirical work. This framework has been utilised in the analysis of video recordings of clinical scenarios and has significantly advanced knowledge and understanding of team interactions in surgery, anaesthesia and emergency medicine (Burtscher et al., 2010, 2011; Kolbe et al., 2012, 2014) and led to the development of new theoretical frameworks of team coordination within these settings (Kolbe et al., 2013). As surgery and emergency care form only a fraction of healthcare provision, the current research seeks to develop from this basis and expand our understanding of interprofessional healthcare teams beyond these contexts, including mental health.

Improving our understanding of how interprofessional teamwork is negotiated across a range of healthcare settings is important for many reasons, including the need to design quality improvement interventions based on understanding the constraints of clinical practice, and to design effective training programmes. The purpose of this study was not to develop another behavioural rating scale, but instead to empirically identify the teamwork behaviours that arise during simulated clinical practice to inform an empirically derived behavioural analysis framework that is applicable across a range of clinical contexts and professional groups, and has the potential to capture the temporal dynamics of teamwork behaviour. Similar to the approach taken by Manser and colleagues in the context of surgery and emergency medicine (Manser et al., 2008; Burtscher et al., 2010) and ethological approaches more broadly (Jones et al., 2016; Troisi, 1999), the goal was to create a flexible and comprehensive behavioural framework of teamwork in healthcare settings, which can be used to explore the complex temporal dynamics of team interactions across a range of clinical settings and contexts. Prominent teamwork theories in healthcare, specifically Salas' big five of teamwork (Salas et al., 2005) and Kolbe and colleagues' Coordination of Acute Care Teams (Co-ACT) (Kolbe et al., 2013), provided a theoretical foundation for framework development and a lens with which to view team interactions. In particular, the distinction between explicit and implicit behaviours, which is fundamental to Co-ACT, was helpful; further, although there is limited supporting empirical evidence for the five teamwork domains proposed by Salas, this was also a useful starting point. We combined these insights with inductive analysis of observed teamwork behaviour to develop the framework. Further theoretical development of the components of effective teamwork is only possible with empirical evidence of how real healthcare teams interact.

The aim of this study was to develop a valid and reliable behavioural framework of teamwork, which is applicable across a variety of healthcare settings and professional groups. In developing this framework, we had three objectives. First, to capture the verbal and non-verbal communication between team members as it unfolded over time. Understanding the complex team choreography is essential to understanding more about teamwork in clinical settings, and yet most investigations into teamwork do not give any insight into this complexity (Valentine et al., 2015). Achieving this requires a nuanced approach that allows us to map the complex interactions of team members as they unfold over time. Second, and building on the first, to develop a generic teamwork analysis framework that describes teamwork behaviour between team members, rather than the accomplishment of clinical tasks or speciality related work. Describing behaviour between team members in this way requires analysis of the complex and nuanced interactions with a level of abstraction from the task in hand that is not possible with the existing speciality-specific tools. The aim was to describe teamwork behaviourally rather than in terms of tasks planned or completed. Third, to provide a framework that could be applied across a range of clinical settings and professional groups. By focusing on behaviour rather than tasks it was possible to develop a framework which is applicable across the diversity of healthcare practice settings in which teams work together for patient care.

2. Method

Ethical approval for the study was provided by King's College London Research Ethics Committee (RESCMR-15/16–1561) in October 2015.

2.1. Sample

Identification of the team behaviours involved iterative, detailed analysis of recordings of simulated clinical scenarios. Simulated scenarios were audio visually recorded as part of routine interprofessional simulation training being delivered across two large simulation centres in tertiary hospitals in an urban setting: one specialising in training staff working in acute care settings, and a second specialising in training staff in acute and community mental health. Scenario participants were all NHS staff attending routine training. Participants included: consultants, senior trainees, and staff-grade doctors across acute care specialities; psychiatrists and psychiatric trainees; acute care nurses, midwives; mental health nurses, nursing assistants and allied health professionals. Simulated clinical scenario topics could be broadly categorised into emergency (e.g. management of a cardiac arrest) or non-emergency (e.g. management of an agitated patient). Each scenario lasted approximately 10–15 min.

For behavioural analysis, 20 video recorded simulated scenarios were purposively selected (not including those viewed live) from available course recordings according to a sampling framework that included course topic, healthcare context, and number of participants. The aim was to ensure they were representative of the range of different types of simulated scenarios available, representing both physical and mental health settings and emergency and non-emergency topics (detailed in Table 1). Only scenarios where all participants had provided informed consent for the recordings to be used for research purposes were selected for analysis. These scenarios were analysed for development of the behavioural framework with a plan to return for further sampling if data saturation was not achieved. Simulated scenarios were video recorded from multiple angles. All sampled scenarios had two or more learner participants present (excluding the presence of actors or embedded participants), involved two or more professional groups, and

Table 1
Simulated scenario topics analysed in development of the framework by clinical setting and task context.

Clinical Setting Context	In-Patient Physical Scenarios	In-Patient Mental Health Scenarios
Emergency	Seizures (n = 2)	Attempted suicide (n = 1)
	Sepsis (n = 2)	Diabetic emergency (n = 2)
	Internal bleeding (n = 1)	Violence and aggression (n = 2)
Non- Emergency (routine)	Busy ward (n = 2)	Patient with a physical injury (n = 3)
	Patient relatives (n = 2)	Patient seclusion review (n = 1)
	Agitated patient (n = 1)	Difficult patient assessment (n = 1)

were centred on the management of a patient.

Finally, an additional sample of nine interprofessional clinical scenarios was chosen for reliability testing of the framework. This cohort involved physical in-patient emergency scenarios involving medical deterioration in pregnancy.

2.2. Procedure

To become familiar with the simulated scenario format and the team communication that arises during a scenario, the lead researcher (ML) observed multiple live simulation training days at two centres (physical and mental health). Here, initial ideas for the framework were developed. However, none of these live scenarios were included in the corpus of scenarios for analysis.

Prominent teamwork theories in healthcare, specifically Salas' big five (Salas et al., 2005) and Co-ACT (Kolbe et al., 2013) provided the theoretical foundation for the purposes of analysis. With this deductive lens as the basis of our initial observations and analysis of the clinical simulations, inductive analysis was used to identify aspects of team interaction that had not yet been articulated by these theoretical frameworks. Thus, our approach combined inductive analysis of simulated clinical team working with a deductive approach based on theoretical approaches to teamwork. The procedure for developing the framework involved three key steps:

Step 1. Micro-analysis of behaviour. Video footage of 20 sampled scenarios was exported into the annotation software ELAN (Sloetjes and Wittenburg, 2008), which allows for the creation of multiple and complex codes as applied to video data (Fig. 1). Scenarios were viewed multiple times by a coder, rewinding and reviewing small sections of video footage to reveal the complex dynamics of the interaction. In these scenarios, teams had been given a specific task. We conceptualised all interactive behaviour (verbal or nonverbal) between team members during a scenario as teamwork behaviours. Individual behaviours that did not involve verbal or nonverbal behaviour directed towards another team member (e.g. reading a document at the back of the room) were not coded.

The speech of each participant was transcribed verbatim, alongside a description of the nonverbal communication between team members. The verbal and nonverbal behaviours were added incrementally, drawing on a variety of communication research methods, including conversation analysis (e.g. identifying repairs in speech (Brinton et al., 1986; Colman and Healey, 2011)) and kinesics (Birdwhistell, 2010) (e.g. eye gaze, gesture use).

Step 2. Refine and Test Cycles. The behavioural analyses were reviewed during data sessions by the interprofessional research team, which consisted of healthcare providers (doctors and nurses), psychologists, human factors experts, and communication researchers. The behaviour codes were iteratively revised and refined by the team. Revised behavioural categories were then applied to scenarios, adding new behaviours into the framework as they emerged in the data. The refine and test cycles continued until saturation was reached, and no new behaviours were evident in subsequent scenarios (Morse, 1990).

Once the observable behaviours had been identified, they were then clustered conceptually by identifying the aim of the behaviour and the

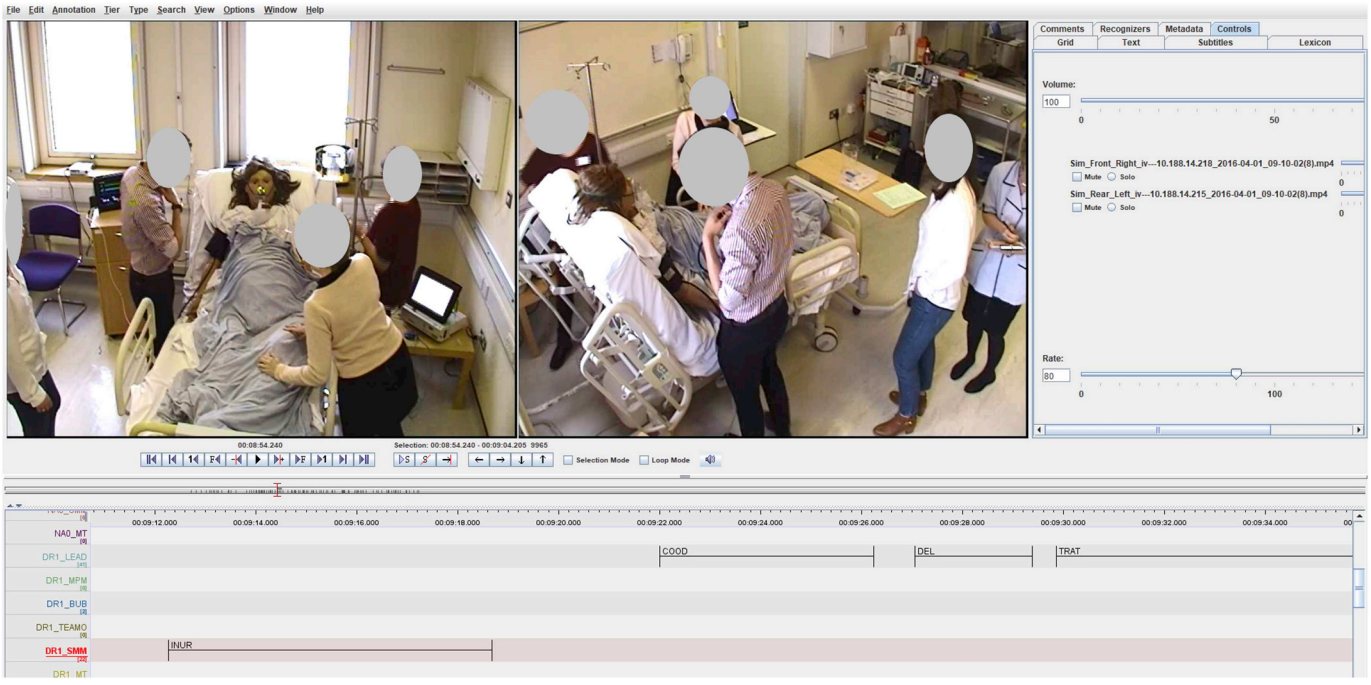

Fig. 1. Example annotation of a scenario in ELAN.

function of the behaviour. For example, helping others to complete their tasks, and completing tasks for others, were conceptualised as having the function of providing assistance. These behavioural functions were further clustered into five overarching teamwork domains, which are similar to Salas' big five of teamwork (Salas et al., 2005) but with some distinctive differences (see Results section).

Step 3. Reliability. Once developed, the final behavioural framework was applied to a different cohort of nine physical emergency scenarios involving medical deterioration in pregnancy. A sample of this cohort was coded in Elan by a second rater using the framework, to establish inter-rater agreement. The rater was provided with ELAN files, incorporating the video footage of the scenario and blank annotations corresponding to the section of video where the behaviours occurred (see Fig. 1 for an example Elan file). The blank annotations were assigned on rows, which are referred to as tiers in the ELAN software. Each tier label indicates the person in the scenario that is displaying the behaviour (e.g. Doctor 1, Nurse 2 etc.) and which of the five teamwork domains the behaviour belongs to (e.g. Leading the team, sharing the mental model etc.). The rater was asked to watch the video footage of the simulated scenarios and assign a behavioural code to each of the blank annotations.

2.3. Statistical analysis

We were interested in identifying the extent to which different coders assign the same precise value for each item being observed (inter-rater agreement) (Bajpai and Chaturvedi, 2015). There is some debate over how this should be assessed in observational frameworks, where the rates of different behaviours vary between categories (Bajpai and Chaturvedi, 2015), which is the case in this framework. For example, some behaviours are seen frequently throughout the scenario, such as information gathering, providing information on request, or information sharing; other behaviours, such as performance monitoring or providing positive comment, occur much less frequently. Cohen's Kappa was used to examine inter-rater agreement.

3. Results

In this section we first present the results of the reliability analysis, followed by a description of the final framework. We then discuss the teamwork domains and illustrate these with data. Finally, we provide an example of the output that can be obtained using the framework.

3.1. Inter-rater reliability

The final framework was applied to a cohort of nine acute care emergency scenarios to determine its reliability. To assess inter-rater agreement, approximately 10% of the behaviours (n = 200) were coded by an independent rater.

Overall, agreement between raters was excellent. Across the whole sample (n = 200 codes), raters agreed on the observable behaviour in 85% of cases. Aggregating these codes into their behavioural functions resulted in 87% agreement between raters. Cohen's Kappa was excellent [observable behaviours - Cohen's Kappa = .79, SE = 0.03; behavioural functions -Cohen's Kappa = .84, SE = 0.03].

The raw percentage agreement between raters for each behavioural function is displayed in Table 2. All behavioural functions showed high levels of agreement between raters (≥78%), with the exception of '*planning*' where agreement was lower (67%).

The agreement levels identified are similar to those seen in other behavioural coding frameworks in comparable complex healthcare settings, e.g. surgery (Kappa = .81) (Jones et al., 2016).

3.2. Final behavioural analysis framework

The final framework is presented in Table 2. Twenty-three observable behaviours were identified. The behaviours are both verbal and non-verbal and in line with previous literature on teamwork coordination (Kolbe et al., 2013). They range from explicit actions or verbalisations (e.g. verbally requesting help from others) to implicit subtle behaviours (e.g. implicit performance monitoring). Once identified, the behaviours were grouped conceptually based on the function they perform. For example, the behaviour of '*assisting others to complete their tasks*' and '*completing others' tasks for them*' both perform the function of '*providing assistance*'. In this way, we clustered the behaviours conceptually into thirteen '*behavioural functions*' (Table 2). The behavioural functions were further categorised into five overarching '*teamwork domains*' (Table 2), which are similar, but not the same as the teamwork categories of Salas' big five model (Salas et al., 2005).

The framework has the flexibility to further specify characteristics of the behaviour, depending on the nature of the interaction, and the level of analysis that may be required. For example, you may wish to code the behaviour alongside who it is being directed towards. Behaviours being used to convey adaptability (e.g. adapting the management of a situation, taking a different approach) were found not to be distinct from other behaviours in the coding frame such as managing a situation or taking action, but are only distinguishable in terms of the context of that behaviour. It is only possible to infer adaptability when the data are analysed sequentially, i.e. we only know that someone is demonstrating adaptability in their behaviour if we know that there has been a change from what was happening previously. Therefore, rather than having a separate team domain for adaptability, the annotation of adaptability (A) or contingency planning (C) can be added to the end of any code, to signify that the behaviour demonstrates adaptability. However, adaptability was found to occur predominantly in the domain of leadership.

In the following sections, we describe each of the behavioural domains and provide some examples of the behaviours involved.

3.3. Leading the team

This teamwork domain includes four functions and eight specific behaviours that can be performed by any team member and are designed to direct and coordinate the activities of the team. There are four leadership functions: *delegation*, which includes instructing other team members to complete tasks and re-distributing workload between team members; *information gathering*, verbally through asking questions; *planning*, through explicit sharing of task and goal setting; and *disseminating rationale*, through coordinating information from multiple sources, disseminating the rationale for a task and verbalising the big picture.

3.4. Developing the shared mental model

This teamwork domain describes behaviours that are used to develop a shared understanding between team members. The identification of these behaviours drew on the conversation analysis literature, particularly a technique called '*repair*', which is a way of amending or fixing our own or others' speech with the goal of achieving a shared understanding (Colman and Healey, 2011). This domain has two behavioural functions. The first is clarifying information, which involves requesting others to clarify what they have said previously (e.g. *did you mean x?*) or reflecting back (repeating) what other team members have said to ensure/clarify that it is interpreted correctly.

The second behavioural function is information sharing. This involves spontaneously speaking to the room/team to share information, without this information being previously requested by another team member. For example, a team member may spontaneously provide information on the patient status (e.g. '*the temperature is 37.*'), or they may

Table 2
Temporal Observational Analysis of Teamwork (TOAsT) in Healthcare: A Framework of teamwork behaviours.

Teamwork Domains	Behavioural Functions	Agreement (%)	Observable Behaviours	Code	Verbal Examples
Leading the team *Direct and coordinate activities of team members.*	**Delegating**	91	**Instruction:** Delegating a task directly to a member of the team	**INS**	'*John put her on the nebuliser*' 'can you get the X'
			Workload re-distribution: Members of the team re-allocating tasks, this may be between other members of the team or between themselves and others.	**WKLD**	*'Anne you seem too busy to do that, John can you do X for Anne'*
	Information Gathering	89	**Requesting information:** Requesting task relevant information from other team members. Requests may also be directed towards the patient. This does not include turns where an instruction is phrased as a question (e.g. can we get the oxygen on?) or questions that require an action rather than a response (e.g. can we get the oxygen on?).	**INFR**	*'Which oxygen mask do you want?' (to team)* *'Have you got any pain in your legs?' (to patient)*
	Planning	67	**Task Setting:** Explicitly setting/stating a task to be completed by the team. This may be delegated to other team members or completed by the individual who set the task. Is the task demonstrating adaptation or contingency planning? If task represents an adaptation of earlier plans code TSET_A. If task represent future contingency planning code TSET_C.	**TSET**	TSET - *We're going to listen to her chest'* TSET '*Can we put her on nebulisers please?'* *Adaptability:* TSET_A - '*I wasn't able to listen to her chest so I'm going to start her on X'* TSET_C - '*If we can't get X we will do Y'*
			Goal Setting: Explicitly setting out team goals. If goals represent adaptation of earlier plans code GSET_A. If goals represent future contingency goals code GSET_C.	**GSET**	GSET – '*We need to stabilize the patient.'*
	Disseminating Rationale	78	**Coordinating Information:** Coordinating information from multiple sources (e.g. temperature, news score information, patient history etc.) and verbalising it for other team members.	**COOD**	*'She's 30 weeks pregnant, known asthmatic, tachycardia and she's looking quite tired.'*
			Big Picture: Explicitly verbalising the providing an overall picture of the situation, which may include providing a diagnosis and providing rationale for the team goals.	**BIGP**	*'At the moment, this looks like we're moving into a life-threatening asthma.'*
			Task Rationale: Explicitly verbalising rationale for tasks that are being set or being completed by the team.	**TRAT**	TRAT – '*Because she is very wheezy*, [*can we put her on nebulisers please?*']
Developing a Shared Mental Model *Negotiation of communication between team members to develop and build a shared understanding.*	**Clarifying information**	84	**Evaluating/clarifying others' contributions:** Asking questions or statements specifically to clarify or evaluate information that someone else has provided.	**INFE**	*'How much salbutamol did you ask me to give?'*
			Information on request: Providing information because it has been requested by another team member. This is frequently seen as responding to a question by another team member or any other individual present.	**INUR**	*How much salbutamol did you give?* INUR - '*I gave X*'
			Reflection: Reflecting back what someone has said to them, in order to ensure that your interpretation was correct.	**CLR**	*I have pain here at my side?* CLR - *'The pain is in your side'*
	Information sharing	78	**Speaking to the room:** Spontaneously providing information to team members about your own actions (VERA) or to provide information (VERI). This information has not been requested by others.	**VER**	VERA – '*I'm putting the oxygen on'* VERI – '*The temperature is X*'
Requesting and Providing Assistance *Providing assistance to team members when they are in need, including recognising a need for assistance and requesting it from others.*	**Requesting assistance**	100	**Requesting assistance:** Asking other team members for help with a task. This may be a request to other members of the team (ASK) or a request for assistance from those outside the team (ASK_E)	**ASK**	'*Can you help me with this' (to Individual)* '*Can we get the medical team in here?' (to team)*
	Providing assistance	100	**Helping others:** Actively helping others to complete their own tasks. This is frequently nonverbal but may also be verbal.	**HELP**	*'Let me hold that for you while you … '*

(*continued on next page*)

Table 2 (*continued*)

Teamwork Domains	Behavioural Functions	Agreement (%)	Observable Behaviours	Code	Verbal Examples
			-In some cases, where verbal information is provided to help others' complete their own tasks this code may also be applied in conjunction with other codes.		
			Completing others' tasks: Taking on others' tasks for them. This is frequently nonverbal but may also be verbal.	**DO**	*'Do you want to give it to me and I can do it'*
Monitoring Team Performance *Monitoring the performance of other team members and providing feedback to them.*	**Explicit Performance Monitoring**	100	**Speaking up:** Explicitly speaking up to question the performance of others, procedure or the course of action that has/is being taken.	**EPM**	*'I don't think you fitted that correctly'*
	Implicit Performance Monitoring	100	**Subtle challenging others' performance:** Using implicit communication to highlight/question the performance/ course of action of team members. This behaviour appears to be designed to get other team members to reflect on/realise their own error or lapses in performance. This is frequently expressed through use of other behaviours e.g. 'speaking to the room' or 'information gathering' alongside nonverbal strategies indicating that a response or action is expected such as holding position or gaze.	**IPM**	*'Is the temperature a bit high?'[INFR]* *'I can't feel a pulse' [very]*
			Nonverbal performance monitoring: Nonverbally monitoring the performance of other team members, usually as they engage in a task.	**NPM**	N/A
Team Attitudes *Valuing team members' and negotiating disagreement*	**Positive attitude**	100	**Valuing others' contributions:** This may be actively seeking out and requesting the opinions or feedback from other team members, or taking into account/considering or accepting others' spontaneously provided opinions/feedback.	**OTHR**	*'what do you think we should do here?'*
			Positive comment: Providing positive feedback to other team members on their performance. This may be very brief comments.	**POS**	*'that was great thanks',* *'well done',*
	Negative attitude	100	**Being ignored by others:** An individual's contributions being ignored by other team members. This code is attached to the contribution that is ignored, which may already have another code (e.g. VERI/A).	**OTHI**	N/A
	Disagreement	100	**Disagreement:** Explicit disagreement between team members, this can be classified as task based – disagreement about a task (DIST) or process based (disagreement about process or procedural issues (DISP)	**DIS**	DIST – *'I don't think we should give salbutamol'* DISP – *'I don't think we should give salbutamol at this stage'*

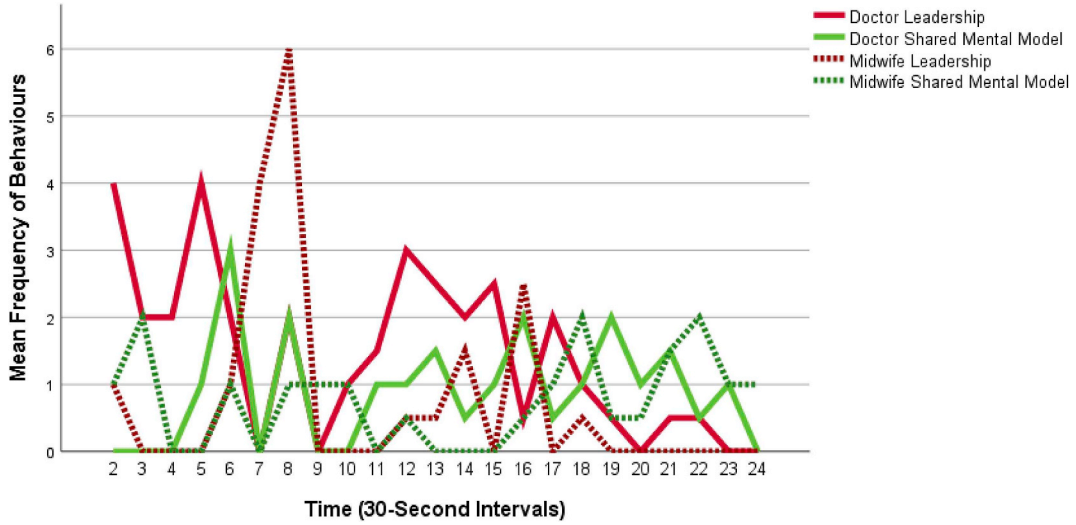

Fig. 2. Mean frequency of behaviours displayed by doctors and midwives in the teamwork domains of leading the team and developing the shared mental model, over the course of a simulated scenario of medical deterioration in pregnancy. This 12-min scenario has been divided into 24, 30-s intervals, which are represented on the horizontal axis (i.e. time interval 2 = 30–60 s).

provide information on their own actions (e.g. '*I'm putting on the oxygen.*'). The critical feature of this function is that the information has not been previously requested by another team member. Within the framework, coders may distinguish between sharing information that is not related to the team member's own actions (VERI) and sharing information that is (VERA).

3.5. Requesting and providing assistance

This domain captures team members' helping behaviour, and has two behavioural functions: requesting assistance, which involves explicitly asking other team members for help; and providing assistance, which involves helping another to complete their own tasks, and completing others' tasks for them. Helping behaviours such as these are frequently nonverbal.

3.6. Monitoring team performance

This domain refers to monitoring the performance of other team members and providing feedback to them on their performance. This domain is comprised of two behavioural functions: explicit performance monitoring, and implicit performance monitoring. Explicit performance monitoring includes the behaviour of 'speaking up' to question the performance of others. By contrast, implicit performance monitoring includes behaviours which attempt to monitor the performance of others but do so without explicitly verbalising their feedback to colleagues. These behaviours include subtle challenges to colleagues. These are coordinated patterns of behaviour (e.g. verbalising actions, requesting information) which appear to be designed to get other team members to recognise their potential errors or lapses in performance. These behaviours were identifiable as performance monitoring events based on the context within which they occurred, and the nonverbal presentation of the person producing the behaviour. For example, a nurse may verbalise information such as '*the temperature is 38*' while gazing towards the doctor, and seemingly anticipating action from them. Identification of such behaviour requires the annotator to consider and assign a rationale for the behaviour.

3.7. Team attitude

This domain refers to team members' cognition, beliefs and attitudes towards teamworking. These psychological features frequently lack verbal expression, which means they are more difficult to ascertain from observational methods. However, the coding did identify observable behaviours which may embody these internal aspects. This domain is comprised of three behavioural functions: *positive attitudes*, *negative attitudes* and *disagreement*. The *positive attitudes* category includes the behaviours of valuing others' contributions through actively seeking others' opinions; requesting others' feedback; responding positively to feedback received from other team members; and providing positive comments and feedback to other team members. The *negative attitudes* category includes the behaviour of ignoring others, which includes being actively ignored by other team members. The final category is *disagreement*, and is categorised by disagreement type: task-based disagreement, relating to disagreement over which task should be completed, or process-based, which refers to disagreement over a process or a procedure. Interpersonal disagreements were not evident in the data, and so have not been included in the framework as a separate and discrete element.

3.8. Example temporal output

To provide an example of the type of temporal output data that can be generated by the framework, the behavioural annotations from one scenario of the reliability cohort (i.e. medical deterioration in pregnancy) were exported from ELAN as a csv file to SPSS version 22 (2013). We were interested in graphically representing the behavioural frequencies over time for the two professional groups (i.e. doctors and midwives) participating in one 12-min scenario. To graphically represent the behavioural time series, we have chosen to present the behavioural data at intervals of 30 s. This is just one method of representing the data; alternatively the data could be examined frame by frame, or using any other interval of data that suits the analytical purpose.

Fig. 2 displays the mean frequency of behaviours displayed by different professional groups (doctors or midwives) in the teamwork domains of leading the team (red) and developing the shared mental model (green) for one clinical scenario. Doctors' behavioural frequencies are presented on the solid lines and midwives' behaviours on the broken lines. The horizontal axis indicates time. The 12-min scenario is divided into 24 intervals of 30 s each. Fig. 2 demonstrates that during the opening moments of this scenario, doctors display high frequencies of leadership behaviours. After the doctors' leadership behaviour has waned there is a sharp but brief increase in leadership by

midwives. This is followed by an increase in leadership behaviour by the doctors. Both professional groups appear to contribute to the shared mental model throughout the scenario, but leadership behaviour is shared and performed sequentially by colleagues from only one professional group at a time.

4. Discussion

Detailed observational analysis of diverse simulated healthcare teams have informed the development of the Temporal Observational Analysis of Teamwork (TOAsT) framework, which is a behavioural coding framework for interprofessional teamwork in healthcare. It is reliable, applicable across a range of clinical contexts, informed by prominent theoretical models of teamwork in healthcare (Salas et al., 2005; Kolbe et al., 2013) and provides empirical evidence of the teamwork behaviours that occur and can be observed during simulated clinical encounters.

This paper presents a flexible framework that supports the analysis of interprofessional teamwork across a range of clinical settings. The strength of this behavioural framework is that it is grounded in observed behaviour in simulated practice, providing empirical evidence of how teams actually work together and communicate with each other. Furthermore, this framework facilitates examination of the temporal features of teamwork. Although this has been achieved before in the context of surgery and anaesthesia (Manser et al., 2008; Burtscher et al., 2011; Kolbe et al., 2012, 2014) the temporal, sequential and interactional aspects of teamwork do not feature in research to date (O'Neill and Salas, 2017). This is the first framework which facilitates temporal analysis across a range of clinical contexts and professional groups, opening the opportunities to examine and compare teamwork across clinical settings, tasks, contexts and professional silos.

The temporal aspect of this behavioural framework can be used qualitatively to provide detailed insights into how the complex dynamics of interprofessional teams occur; the potential influence of different professional combinations; and how aspects of teamwork unfold over time. When used as designed, with video data annotated in appropriate software with data exporting features, the framework can also provide behavioural frequencies or durations. This enables a variety of statistical comparisons across clinical settings or tasks, or correlations between teamwork and clinical task performance (Lavelle et al., 2019). Given that an understanding of teamworking in healthcare is still evolving, it may be premature to develop rating scales and instruments without first having an understanding of which behaviours are necessary for effective team functioning, and how behaviours relate to each other. A descriptive analytical framework such as TOAsT can enable further research into whether and how different teamworking behaviours and patterns of interaction are related to team outcomes, thus building an empirical evidence base for the complex dynamics of team interaction in healthcare.

Theoretical explanations of teamwork stress the importance of adaptability (Salas et al., 2005). However, analysis of the scenarios revealed that the behaviours being used to convey adaptability (e.g. adapting the management of a situation) were not distinct from other behaviours already set out in the coding framework (e.g. task setting, disseminating rationale), but were distinguishable because the context within which that behaviour occurred had changed. It is only possible to infer adaptability when the data are analysed sequentially: we only know that someone is demonstrating adaptability in their behaviour if we know that there has been a change. This is a nuance that requires a temporal analytical lens, such as this framework, to identify and document.

A recent review of teamwork performance measurement synthesised all teamwork tools currently in use in the context of healthcare (Marlow et al., 2018). This review revealed nine validated behavioural observational tools which are used to assess teamwork in healthcare settings (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009; Fletcher et al., 2003; Lyk-Jensen et al., 2014; Cooper et al., 2010; Frankel et al., 2007; Weller et al., 2011; Taylor et al., 2012). Unsurprisingly, the categories identified in the TOAsT framework overlap with those identified in other behavioural observational tools, as they share a common purpose and are addressing shared constructs. However, the TOAsT framework differs from these other observational teamwork tools in several important ways. The first difference is the applicability of the tool across healthcare settings. All previous tools have focused on teams in physical healthcare settings, with the majority of instruments designed for use in the context of anaesthesia (Fletcher et al., 2003; Lyk-Jensen et al., 2014; Manser et al., 2008), surgery (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009) or critical care (Cooper et al., 2010; Weller et al., 2011). The TOAsT framework and the Communication and Teamwork Skills (CATS) assessment (Frankel et al., 2007) are the only measures developed for use with healthcare teams more broadly. However, TOAsT is the only framework to be developed with consideration of healthcare settings beyond the physical healthcare domain. The second major difference between the current framework and existing instruments is scoring. All other tools require an observer to make a judgement about the performance of that behaviour (good to poor) (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009; Fletcher et al., 2003; Lyk-Jensen et al., 2014; Cooper et al., 2010; Frankel et al., 2007; Weller et al., 2011; Taylor et al., 2012). The TOAsT framework requires raters to code the behaviour when it is present, with no judgement on how well it was performed. The third major difference is the range of behaviours the tools capture. Of the nine tools identified in the review by Marlow and colleagues, five did not capture the teamwork components of providing or requesting assistance (Yule et al., 2006; Lyk-Jensen et al., 2014; Cooper et al., 2010; Weller et al., 2011; Taylor et al., 2012) and six did not capture the behaviours of monitoring performance of other team members (Yule et al., 2006; Mishra et al., 2009; Lyk-Jensen et al., 2014; Cooper et al., 2010; Frankel et al., 2007; Taylor et al., 2012), both of which have been identified in the current analysis and have been deemed important in theoretical explanations of team work (Salas et al., 2005).

Furthermore, the TOAsT framework captures behaviours that reflect team members' attitudes to teamworking, which are not captured by other observational tools (Undre et al., 2009; Yule et al., 2006; Mishra et al., 2009; Fletcher et al., 2003; Lyk-Jensen et al., 2014; Cooper et al., 2010; Frankel et al., 2007; Weller et al., 2011; Taylor et al., 2012) or observational frameworks (Manser et al., 2008). It is difficult to identify behavioural markers of these constructs, which is demonstrated by a lack of these components of teamwork in other observational measures (Marlow et al., 2018). However, our detailed temporal analysis of clinical scenarios identified behaviours that appear to convey these aspects (e.g. *positive comments, valuing the opinions of others, ignoring others*). The list of behavioural markers in this teamwork domain is not extensive, but their presence or absence may lead to the emergence of different teamworking patterns and they may be a powerful behavioural predictor of teamwork performance. Another behaviour that we anticipate could fall into the category of negative attitudes, which we didn't see in the current study and as such has not been included in this framework, was responding negatively to others' feedback. The lack of this behaviour in the current cohort may have been due to the simulated nature of these interactions. Future studies examining healthcare teams in-situ may identify such behaviours.

The framework developed in this study also offers an educational application, providing a shared language for teamwork behaviour which spans professional backgrounds and settings. Simulation training is a good vehicle for developing interprofessional teamwork skills in healthcare, providing experiential and reflective components, which facilitate participants' development and practice of their teamwork skills, while refining their attitudes about interprofessional working (Weaver et al., 2014; McGaghie et al., 2016). This framework

may be used to scaffold discussions around teamwork during post scenario debriefs. It may also be used to further analyse the potential impact of elements of simulation-based training that currently have little or no empirical basis, such as what role an embedded simulation practitioner (sometimes referred to as a plant or confederate) should take, and what impact this could have on team learning or patterns of behaviour.

A limitation of this study was the use of data from simulated clinical interactions, rather than genuine clinical interactions with live patients. However, one rationale for simulation training is that it has real world fidelity and can elicit realistic behaviour without risk to patients; because of this, we are confident that we have accurately captured many central aspects of team behaviour. Moreover, the iterative analysis required would not have been possible without video recordings, and recordings of clinical practice are difficult to obtain due to practical and ethical considerations. Analysis of simulated practice videos is frequently used in the examination of healthcare teams (Schmutz and Manser, 2013) for these reasons. Our team is considering how the framework can be turned into a digital tool for conducting live behavioural analysis of healthcare teams at work in patient care settings.

5. Conclusion

Much of the theory, and some of the associated recommendations for improving and measuring team working within healthcare, do not take into account many of the realities of how teams care for patients in clinical settings. Although several observational teamwork performance measurements exist (Marlow et al., 2018), they have been developed for specific settings and provide a summative score, meaning they can be used for benchmarking teamwork performance but have limited utility for analysing teamwork more comprehensively. The behavioural analysis framework reported here allows for the recording and further analysis of the many nuances of clinical practice, including the ways in which individual team members' behaviour is related to what other colleagues do, and how behaviour patterns develop over time. This in turn gives an opportunity to study team behaviour in more depth, including how teamwork may link to clinical outcomes. We argue that this behavioural analysis framework can be used to deepen our understanding of these patterns. Its grounding in the empirical observation of clinical behaviour across a range of contexts is a major strength, as is its strong basis in theoretical conceptions of teamwork. The knowledge generated can help us develop better ways of training and preparing clinicians to work in high-performing, patient centred care teams.

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Conflicts of interest

The authors have no competing interests to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apergo.2019.102915.

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