A Systematic Literature Review on Design for Supporting Systems Intelligence of Interdependent Teams

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High Systems Intelligence (SI) is related to emotional, cognitive, behavioural and wellbeing benefits. With the aid of SI, teams can be better understood, supported and optimised with design as SI explains the intelligent behaviour of complex human systems involving feedback and interactions. However, understanding SI in designing for teams in human-computer interaction is understudied. The goal of this study is to explore design for interdependent teams through the lens of SI. This paper employed a systematic literature review of 57 published journal and conference publications between the years 2013–2023 to 1) integrate previous research and 2) create a framework for SI design solutions supporting the teamwork of interdependent teams. The results reinforced existing definitions of SI factors but also extended them by incorporating human-computer interaction (HCI) context-specific elements in interdependent teamwork. SI framework provides a theoretical contribution for academics and an applied contribution for practitioners when designing for interdependent teams in HCI.

CCS CONCEPTS • Human-centered computing~Human computer interaction (HCI)~HCI design and evaluation methods • **Human-centered computing~Human computer interaction (HCI)~Interaction paradigms~Collaborative interaction** • **Human-centered computing~Human computer interaction (HCI)~HCI theory, concepts and models** • **Social and professional topics~Professional topics~Management of computing and information systems~Project and people management~Systems development**

Additional Keywords and Phrases: Systems Intelligence, Systematic literature review, Interdependent teams, Design

ACM Reference Format:

First Author's Name, Initials, and Last Name, Second Author's Name, Initials, and Last Name, and Third Author's Name, Initials, and Last Name. 2018. The Title of the Paper: ACM Conference Proceedings Manuscript Submission Template: This is the subtitle of the paper, this document both explains and embodies the submission format for authors using Word. In Woodstock '18: ACM Symposium on Neural Gaze Detection, June 03–05, 2018, Woodstock, NY. ACM, New York, NY, USA, 10 pages. NOTE: This block will be automatically generated when manuscripts are processed after acceptance.

1 INTRODUCTION

Modern teams are characterised by the interdependence between actors. In a rapidly changing, interconnected world, the concept of interdependent teams enhances the understanding of teamwork across diverse fields such as work and sports. As the complexity of projects increases, so does the interdependence within a team and the necessity for holistic approaches to problem-solving (e.g. [73, 87]). Interdependent interaction between team members is not required for effective taskwork, but the interdependence of interaction and activity is required for successful teamwork [36, 87]. When teams have more interdependence, the relationship between efficacy and performance is higher [36, 87]. Modern expert work, from startups to multinational corporations and ecosystems, is organised in an interconnected way. Nowadays, to solve problems, conventional siloed or linear thinking is seen as inadequate, necessitating a shift toward more holistic and systemic perspectives.

Systemic design is a broadly developing interdisciplinary field which leverages insights from systems thinking theories and involves stakeholders as active participants in co-designing [41]. It aims at improving societal or environmental outcomes with a longer-term focus compared to previous problem solving or product-oriented design approaches [41]. Systemic design can be used, for instance, to improve organisations, policies, social programs or service systems [41]. Although systemic design principles, methodological toolkits, practices and conceptual frameworks have recently been proposed [10, 41–44, 76], they are immature in understanding and designing for interdependent teams.

Systems Intelligence has the potential to offer a lens to understand, support and design for interdependent teams. Saarinen and Hämäläinen [84] have introduced the ability of Systems Intelligence (SI) to explain intelligent behaviour in the context of complex systems involving feedback and interaction. It relates to a person's ability to act in systems and reason about them to create actions adaptively, which are productive within and with respect to systems like family, teams, organisation and everyday life [84]. Instead of modelling systemic structures, SI is outcome-oriented with a bottom-up approach, interactional, context-specific and optimistic in its actual life focus [37]. SI is characterised by the whole, acknowledging interconnectivity, interdependence, and systemic feedback, and it correlates with systemic behaviours (e.g. emotional intelligence, organisational learning, wellbeing and performance [44, 84, 106]). In modern teamwork, thinking in systems and through interdependence is vital for success (e.g. [58, 69]). SI theory can help to frame design for these interdependent teams through its eight SI factors: systemic perception, attunement, positive attitude, spirited discovery, reflection, wise action, positive engagement and effective responsiveness [37]. A new broadened focus of design underlines the need to move from methods towards frameworks [52, 88]. Recently, 32 SI tactics have been proposed to support designers' work [44]. However, there is no previous research summarising how to design for SI in the context of interdependent teams.

The goal of this paper is to construct a framework for SI supporting the teamwork of interdependent teams based on a systematic literature review. The current understanding of SI in design for teams in human-computer interaction (HCI) is currently limited in both theory and practice. The systematic literature review examines 57 published high-quality publications during the years 2013–2023. It explores the design process and its outcomes, which are designed to support SI of interdependent teamwork across a spectrum of contexts. The novelty of the paper is to summarise past research through the lenses of SI, design and interdependent teams. Through this, the paper presents a framework to guide designers' work, provide an overview and assist in directing future research. The results of this paper will benefit both human-computer interaction (HCI) practitioners and academics understanding and designing for SI in the context of interdependent teams.

2 RELATED WORK

2.1 Interdependent teams

A team is defined with three elements: it includes multiple people who are interdependent and have a shared goal [87]. Teams are critical success factors of organisations as they enable flexible, rapid and adaptive responses to unexpected situations [49]. Interdependence refers to the extent to which members of a specific team must rely on each other and co-operate to deliver the solution [86]. Interdependent teams can appear, for example, in the workplace and also in team sports [60, 73]. Team performance and effectiveness have been the focus of studies of successful teams [60]. Research shows that effective teamwork includes sharing knowledge, coordinating behaviours and trusting one another [60]. The modern workplace has witnessed a transformation in recent decades, characterised by the increasing complexity of tasks, the rapid pace of change and the emergence of highly interdependent teams [60]. Teams can be different based on their history, working styles and dynamics, as some might have a long history of working together, whereas some teams or team members might be complete strangers [60]. Teams can work entirely face-to-face, online or through hybrid models and members may also change during the project or phases [60]. All of this affects the developmental stages, progress towards the goal and stage of interdependence or relationships of a team [60]. The concept of interdependent teams constitutes the grounds of this review.

2.2 Systems Intelligence

Systems Intelligence relates to a person's ability to act in systems and reason about them to create actions adaptively that are productive within and with respect to systems like family, organisations, teams and everyday life [84]. When people are observing their interdependence in an environment that is feedback intensive, they can act intelligently [37]. It has been shown that SI correlates with emotional intelligence, wellbeing and perceived performance in organisations. [44, 84, 106]. A system is characterised by interconnections and the internal nature of its elements; it produces effects and has generative power [37]. A human system can be, for example, a team, family or organisation. [84]. SI aims to shift focus from individuals getting along with others to creating better systems with others and focusing on teams and organisations as a whole [104]. With its multidisciplinary roots, SI has been applied in different fields [44]. Drawing from disciplines such as systems thinking, change leadership, philosophy of everyday activity and understanding human subjectivity, SI finds its applications in fields like organisational leadership, communication, psychotherapy, arts leadership, engineering education and emergency management [38, 47, 55, 59, 85, 91]. It offers a comprehensive framework to address systemic and complex global challenges [84]. SI involves the ability to perceive and comprehend complex systems, anticipate their dynamics and intervene effectively to optimise outcomes [37, 84]. Transcending individual capacities, SI extends to teams as a whole, facilitating a shift from 'parts thinking' to 'whole thinking' [84].

Hämäläinen et al. and Törmänen et al. [37, 105] have developed an eight-factor model for SI components. These factors describe the aspects of SI behaviour, which are systemic perception, attunement, wise action, reflection, positive attitude, spirited discovery, positive engagement and effective responsiveness. The first factor, systemic perception, is described as an ability to see, identify and recognise different systems or interconnections. In other words, having situational awareness. Attunement means engaging oneself intersubjectively or being on the same wavelength as others. A positive attitude is considered as having a positive outlook and not focusing on negative elements. Spirited discovery is an extension of a positive attitude, as it is an open attitude toward new ideas and changes. Reflection means reflecting upon one's thinking and challenging one's own behaviour. Wise action relates to longer-term thinking and understanding the implications of it. Positive engagement is described as considering and encouraging other people. Emotional intelligence is highly related to this factor. The last factor, effective responsiveness is considered as a conformity to purpose and awareness of it. It is an efficient utilisation of expertise, environment and systems to achieve the goal. These factors affect people's behaviour in everyday life, work and free-time-related situations [37, 105]. To make it more comprehensible, Tiinanen et al. [104] have grouped the eight-factor model of SI into four characterising pairs. The characterisation has been done by grouping statistically and conceptually related factors together. The first pair is perceiving systems (systemic perception, attunement), the second pair is called attitude (positive attitude, spirited discovery), the third one is thinking (reflection, wise action) and the final pair is related to acting (positive engagement, effective responsiveness) [104]. The factors, pairs and descriptions for each factor are described in Table 1. SI and its implications in diverse teamwork development and design processes are still understudied. The previous SI research has formed a good theoretical ground and indicated its capabilities. Nonetheless, there is a need to adapt SI to the development of design solutions for teams.

Table 1: Systems Intelligence factors, characterising pairs and descriptions [37, 104, 105].

Factor	Pair	Description
Systemic perception	Perceiving	Seeing, identifying and recognising systems, patterns and interconnections and having situational awareness.
Attunement	Perceiving	Engaging intersubjectively, being present, mindful, situationally sensitive and open.
Positive attitude	Attitude	Keeping a positive outlook, and not getting stuck on negative impressions and effects.
Spirited discovery	Attitude	Engaging with new ideas, embracing change.
Reflection	Thinking	Reflecting upon one's thinking and actions, challenging one's own behaviour.
Wise action	Thinking	Exercising long-term thinking and realising its implications, understanding that consequences may take time to develop.
Positive engagement	Acting	Taking systemic leverage points and means successfully into action with people.
Effective responsiveness	Acting	Taking systemic leverage points and means successfully into action with the environment, being able to dance with systems.

2.3 Design research, process and outcomes

Design is a comprehensive perspective, combining various viewpoints on challenges and their surroundings [57]. It considers technology, needs and empathy towards users and stakeholders in order to craft artefacts that carry significant depth of meaning [57]. Research through design is characterised by its emphasis on employing methods and processes from design practice as a method for inquiry [48]. As a holistic approach where knowledge and theory integrate from multiple disciplines, research through design reframes challenging situations and the state preferred in interactive processes [48]. The concept of constructive design research is developed based on the criticism regarding the research through design approach [48]. Constructive design research focuses on design research in which a product, system, space or media, for instance, is its central element in knowledge construction [48]. Within this approach, design itself is described as an active process of knowledge generation [50]. Constructive design research integrates design and research [50]. It develops design research from studio work to practice and utilises best practices from research through design. In contrast, research through design focuses more on translating design practice methods and processes to a research environment [50]. These approaches have gained attention in diverse fields, such as human-computer interaction, design and fashion [24, 48, 116].

Although there is no unified view on design processes, they typically cover phases of understanding users, defining focus, creating ideas, generating prototypes and testing with users, and it is iterative in its nature [64]. A characteristic element of design approaches in research is that they entail designing and deploying some kind of prototype in the process [64]. Contributions to research design can be artefacts, theories, frameworks, design recommendations, methods and design implications [116]. Giaccardi [32] describes that artifacts can demonstrate possibilities, speculate on alternative futures, work as tools to develop theories or represent examples of potential devices. One central reason for creating artefacts is to support a reflection process with the design activity to get feedback on its usefulness and functionality [32]. These contributions have the potential to be utilised for purposes such as evaluating design outcomes, testing empirical hypotheses, supporting material exploration, addressing concerns and inspiring alternative perspectives [32]. Although design research and design thinking are widely adopted, there is a need to understand, adapt and apply them in the new domain of SI and to develop design solutions for interdependent teams.

2.4 Previous related reviews

Teamwork, organisational teams and sports teams have received much attention in research previously, and different literature reviews focus on interdependent teams as well. Topics of interdependent team reviews have been, for instance, work team’s resilience towards the turbulent business environment by creating a theoretical framework on how to build resilient work teams [99], comparison of different forms of multiteam systems [115], evaluating the impact of environment on clinician teamwork and its effectiveness [72] and the current knowledge on how to improve the relationship of a patient and care partners as an interdependent team [9]. From the SI perspective, few literature reviews have been conducted, but the most recent one deals with a conceptual model of arts leadership through the lens of SI [47]. As the concept of SI is based on systems thinking [90] and emotional intelligence [34], previous reviews based on these topics can be considered as background as well. The previous reviews have focused on assessing systems thinking in engineering [23] and reviewing the role of different intelligences in teams [22]. In regards to reviewing design solutions from a team perspective, a systematic literature review has been conducted regarding the effects of interactive technologies on team effectiveness [31]. There are some previous reviews and new research-generated frameworks in the field. However, they are focusing, for example, on a work-based framework for interdependent group work [35], integration of teamwork behaviour frameworks [83] and creating a framework for systems thinking characteristics in improving health actions [103]. Although previous research has tackled some elements of reviewing interdependent teams and SI-related concepts, there is a gap in a clearer understanding of SI supporting interdependent teamwork in HCI and how to design solutions supporting it.

3 METHODS

The research questions of this study are: What is the design for SI in interdependent teams? How has SI in interdependent teams been studied during the last ten years? This study aims at 1) integrating previous research, 2) understanding the current design solutions for SI and 3) creating a framework for future research in the field of SI supporting teamwork. In this review, design is considered as a process and outcome [32, 64, 116]. Interdependent teams are defined as teams in which members must rely on each other and co-operate to deliver the solution [86] and SI is approached through its eight factors [37]. A systematic literature review was conducted according to Okoli's guidelines [70]. The approach followed the process of eight steps to conduct a rigorous review that sums up and discusses the existing literature on the defined research questions. The findings of the systematic literature review are summarised in consecutive sections.

3.1 Search process

In order to gain an overview of the existing literature on the topic, two keyword sets were defined to cover different aspects of the scope. The first set of keywords focused on teams and the second on design solutions. The boolean operator AND was used to combine keyword sets so that each retrieved article was related to at least one term from the first and one from the second set. Table 2 presents all keywords used.

Table 2: Keywords used in the search process.

Set	Keywords
Teams	team*, interaction, communication, interdependent, collabor*, group*, interpersonal, *feedback
Design solutions	service, product, technological solution, process, procedure, solution, proto*, system*

Two databases, ACM Digital Library and Scopus, were utilised to perform the search, and it was limited to only original research and conference papers written in English. The search in the databases was limited to articles published between 2013–2023 to obtain a realistic and accurate outlook on the topic. The detailed search queries are presented in Appendix 1. Figure 1 illustrates the phases of the selection process in the form of a flow chart.

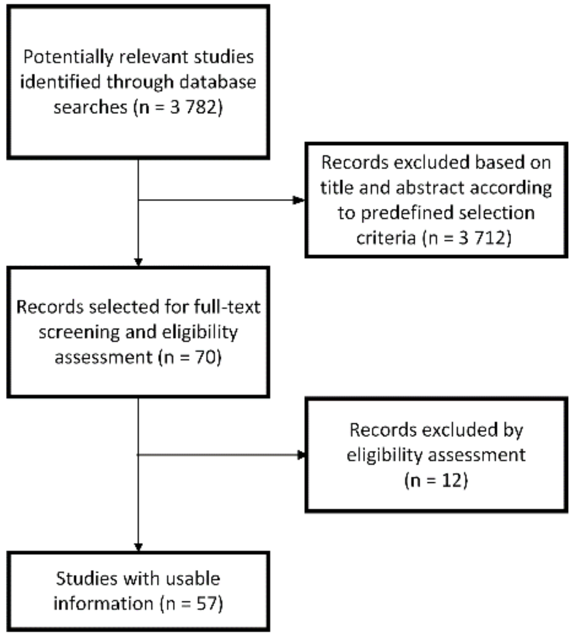

Figure 1: Selection process illustrated in the form of a flowchart.

The initial first phase search created 3 782 results altogether from both databases. All articles were inspected manually based on titles and abstracts in the second phase. The following criteria for selection were used:

- Including teamwork that can be defined as interdependent.
- Using design as a tool to improve teamwork.
- Including at least one of the SI's eight factors.

If there were any doubts regarding the suitability of selection criteria for records, the articles were included for later assessment of the full texts. All papers were collected electronically. During the second phase, 3712 articles were excluded based on titles and abstracts according to predefined selection criteria. This manual inspection resulted in 70 articles being selected for full-text screening. The third phase consisted of an eligibility assessment of full texts, which was conducted by the first author and the same selection criteria were used as presented above. Any inconsistencies in including or excluding records were reviewed by the second author. During this phase, 12 articles were excluded because the content was not related to the review when examined further based on the full text. After inspection of the full-text version, the most prominent reasons for exclusion were that teamwork could not clearly be considered as interdependent (5 records) or it illustrated existing theory rather than including concrete design (5 records). Another reason for exclusion was that some articles did not elucidate SI. Throughout this process, the selection of 57 records in total was formed.

3.2 Data analysis

In analysing the data, phases of bottom-up thematic analysis outlined by Braun and Clarke [11] were followed. The objective was to identify patterns within findings through systematic analysis steps, making it applicable for a research area with limited prior knowledge such as design for SI of interdependent teams. Three phases of the analysis were: 1) Familiarisation with data was done by reading through the selected articles. In this phase, initial codes for pieces of meaningful text were extracted (target group, research methodology, evaluation measures, SI factors, design thinking phase and design outcome). When examining SI factors, the size of one unit of analysis (a piece of text containing one coherent thought) was characteristically one sentence to three sentences long. Initial coding for SI factors was completed based on the definitions presented in Table 1. 2. Grouping of codes and finding themes: The grouping of codes was done based on the similarities, which assisted in finding the initial themes under each of the SI factors. A total of 134 codes were grouped. Definitions and names for the themes were done in parallel by two researchers. 3) Classification of articles: Data analysis continued with the classification of codes. The initial codes were iterated to find the final themes. As classification into one theme in each section was challenging, non-mutually exclusive categorisation was used. This phase was done by one researcher. For the purpose of evaluating intra-rater reliability, grouping and classification of all codes was reconducted three months after the original analysis (100% similarity in grouping and classification).

4 RESULTS

All 57 articles included in the analysis are categorised based on target groups, methodologies, evaluation measures, SI factors, design thinking phases and outcomes in Table 3. Figure 2 presents the distribution of publication years within the selection of existing literature between the years 2013–2023. The years 2013 and 2014 were the publication peaks within this timeframe (20/57 papers).

Table 3: Overview of the reviewed articles. NA means not available.

		Reference												
		[2]	[3]	[4]	[5]	[6]	[7]	[12]	[13]	[14]	[15]	[16]	[17]	[18]
Target group	Students													
	Families or close friends			NA	NA		NA					x		
	Organisations	x	x			x		x	x	x	x		x	x
Methodology	Quantitative	NA		x	x	x	x	x	x	x	x	NA	x	x
	Qualitative		x		x	x	x	x						x
Evaluation measure	Interview/focus group					x					x			
	Observation		x						x					
	Questionnaire	NA			NA	x	x	x	x	x		NA		x
	Log file			x		x	x		x					x
	Diary or notes							x						x
	Agent-based simulation												x	
SI factor	Systemic perception	x							x					x
	Attunement					x						x		
	Positive attitude													
	Spirited discovery									x				
	Reflection				x	x								
	Wise action	x					x	x					x	
	Positive engagement		x	x							x	x		
	Effective responsiveness			x										x
Design thinking phase	Understanding users		x					x			x			
	Defining focus			x	x			x			x		x	
	Creating ideas		x		x		NA	x		NA			x	
	Generating prototypes	x				x		x	x			x		
	Testing with users					x		x	x					x
Design outcome	Theory			x				x			x			
	Framework								x					
	Design recommendation				x	x				NA				NA
	Method		x				x						x	
	Design implementation	x				x		x				x		

		Reference												
		[19]	[20]	[21]	[25]	[26]	[28]	[29]	[30]	[33]	[39]	[40]	[45]	[53]
Target group	Students	x				x								
	Families or close friends									NA				
	Organisations	x	x	x	x	x	x	x	x		x	x	x	x
Methodology	Quantitative		NA	x	x	x	x	x	NA	x			x	x
	Qualitative	x		x	x		x	x		x	x	x	x	x
Evaluation measure	Interview/focus group	x		x	x		x				x	x	x	
	Observation											x	x	x
	Questionnaire	x	NA	x		x	x		NA	NA			x	x
	Log file			x	x	x		x						
	Diary or notes													
	Agent-based simulation													
SI factor	Systemic perception		x			x				x				
	Attunement			x				x						x
	Positive attitude	x					x							
	Spirited discovery											x		
	Reflection	x		x	x									
	Wise action				x									
	Positive engagement							x			x			
	Effective responsiveness		x				x	x	x				x	
Design thinking phase	Understanding users		x		x		x				x		x	
	Defining focus		x		x		x		x	x			x	
	Creating ideas		x			NA	x	NA						
	Generating prototypes	x	x	x								x		
	Testing with users	x		x								x		x
Design outcome	Theory				x									
	Framework		x		x		x	x	x	x				
	Design recommendation										NA		x	
	Method					x								
	Design implementation	x		x								x		x

		Reference												
		[54]	[56]	[58]	[61]	[63]	[66]	[67]	[68]	[69]	[71]	[74]	[75]	[77]
Target group	Students				x					x				
	Families or close friends	NA	x											x
	Organisations			x		x	x	x	x	x	x	x	x	
Methodology	Quantitative	x		x	x	x		x	NA	x		NA	NA	
	Qualitative		x	x	x	x	x	x			x			x
Evaluation measure	Interview/focus group		x	x	x	x	x	x			x			x
	Observation	x	x		x									x
	Questionnaire	x		x	x			x	NA	x		NA		
	Log file					x				x				x
	Diary or notes													
	Agent-based simulation												x	
SI factor	Systemic perception			x	x				x		x		x	
	Attunement	x										x		x
	Positive attitude		x							x				x
	Spirited discovery		x			x								
	Reflection													
	Wise action													
	Positive engagement	x						x			x			
	Effective responsiveness						x							
Design thinking phase	Understanding users		x	x		x		x		x	x			x
	Defining focus	x	x			x	x	x		x	x			x
	Creating ideas	x	x			x	x	x					NA	x
	Generating prototypes			x	x	x	x		x		x	x		
	Testing with users				x		x	x	x					
Design outcome	Theory										x			
	Framework	x				x		x					x	
	Design recommendation			x		x		x		x	x			x
	Method		x						x					
	Design implementation				x		x					x		

		Reference												
		[79]	[80]	[81]	[82]	[89]	[93]	[95]	[96]	[98]	[100]	[101]	[102]	[107]
Target group	Students				x						x	x	x	
	Families or close friends						NA	x		x				x
	Organisations	x	x	x		x			x		x			
Methodology	Quantitative				x	NA	x	x	x		x	NA	x	x
	Qualitative	x	x	x	x			x		x			x	
Evaluation measure	Interview/focus group				x			x		x			x	
	Observation		x	x	x									
	Questionnaire	x		x	x	NA	x	x	x		x	NA		NA
	Log file				x		x				x		x	
	Diary or notes		x					x						
	Agent-based simulation													
SI factor	Systemic perception	x			x									
	Attunement						x				x			x
	Positive attitude													
	Spirited discovery								x					
	Reflection							x						
	Wise action	x												
	Positive engagement		x							x			x	
	Effective responsiveness			x		x						x		
Design thinking phase	Understanding users	x	x	x				x	x	x			x	
	Defining focus			x	x	x			x				x	
	Creating ideas		x	x		x			x		NA			
	Generating prototypes				x		x	x				x		x
	Testing with users	x	x		x		x	x						x
Design outcome	Theory					x								
	Framework			x						x	x		x	
	Design recommendation	x			x			x						x
	Method		x				x		x					
	Design implementation						x	x				x		

		Reference				
		[108]	[109]	[111]	[112]	[114]
Target group	Students					
	Families or close friends		x			x
	Organisations	x		x	x	
Methodology	Quantitative	NA		x	x	x
	Qualitative		x		x	x
Evaluation measure	Interview/focus group	NA	x			x
	Observation		x			
	Questionnaire			x		x
	Log file			x	x	x
	Diary or notes					x
	Agent-based simulation					
SI factor	Systemic perception					
	Attunement			x		x
	Positive attitude		x			
	Spirited discovery				x	
	Reflection					
	Wise action	x				
	Positive engagement					x
	Effective responsiveness					
Design thinking phase	Understanding users		x		NA	x
	Defining focus		x	x		
	Creating ideas	x	x			
	Generating prototypes		x			x
	Testing with users		x			x
Design outcome	Theory	NA	x		x	
	Framework					
	Design recommendatio n		x	x		x
	Method					
	Design implementation					

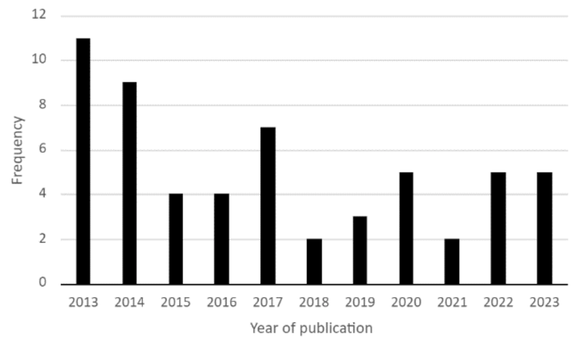

Figure 2: Years of publication of selected articles.

Most of the selected papers were published in conference proceedings (52 papers, 91%), and the rest were published in scientific journals (5 papers, 9%). The studies were predominantly published in the fields of computer science and engineering, as well as design and interaction, with the majority situated in the interdisciplinary domain of human-computer interaction. Most studies focused on organisational teams (39 studies), and only eight concentrated on families or close friends. Some papers (8 studies) had student teams as their target group even though the perspective was on the organisational teams in future research. Both quantitative methods (34 studies) and qualitative methods (33 studies) were utilised, and mixed methods were employed in up to 21 studies. The most common evaluation measures were questionnaires (26 studies) and interviews (23 studies), often in combination with other evaluation measures or each other, which aligns with the distribution of research methodologies. Log files (19 studies) and observation (13 studies) were the subsequent most used evaluation measures, leaving diary or notes (5 studies) and agent-based simulation (2 studies) the least employed ones. In some papers, a particular categorisation was not applicable, or the information needed was not available.

4.1 Systems Intelligence in the review

All eight SI factors have been studied. Table 4 presents the generated themes of SI in design for interdependent teams based on the literature review and a cross-tabulation of related design thinking phases. The factors of systemic perception (13 papers), attunement (13 papers) and positive engagement (13 papers) were the most addressed. These were followed by factors of effective responsiveness (11 papers) and wise action (7 papers). The least investigated factors were positive attitude, spirited discovery and reflection (6 papers each). Seventy per cent of papers focused only on one SI factor, whereas 30% of papers included at least two factors. Six of the studies included the entire or nearly entire design thinking process (4–5 phases), and they targeted different SI factors. Other studies dealt with fewer phases of design thinking. The following sections summarise factor-by-factor design for SI of interdependent teams and related themes

Table 4: Themes of Systems Intelligence in design for interdependent teams and cross-tabulation of Systems Intelligence factors and design thinking phases.

SI factor	Description from the literature review	Design thinking phases addressing the definition				
		Understanding users	Defining focus	Creating ideas	Generating prototypes	Testing with users
Systemic perception (13 codes)	**Collaboration support:** Supporting collaboration and information sharing	2	2	1	5	4
	Awareness: Improving situation awareness and facilitating transparency	2	2	0	3	2
		[20, 58, 71, 79]	[20, 33, 71, 82]	[20]	[2, 13, 20, 58, 61, 68, 71, 82]	[13, 18, 61, 68, 79, 82]
Attunement (13 codes)	**Behavioural signals:** Supportation for nonverbal and attentional behaviour	0	2	1	3	3
	Emotions: Sharing emotions and communicating closeness	2	1	1	4	3
		[77, 114]	[54, 77, 111]	[54, 77]	[6, 16, 21, 74, 93, 107, 114]	[6, 21, 53, 93, 107, 114]
Positive attitude (6 codes)	**Discussion:** Improving open dialogue and socialisation	2	2	1	2	2
	Experiences: Supporting positivity and reducing negative experiences	2	2	2	0	0
	Empathy: Providing empathy, validation and support	1	1	1	0	0
		[28, 56, 69, 77, 109]	[28, 56, 69, 77, 109]	[28, 56, 77, 109]	[19, 109]	[19, 109]
Spirited discovery (6 codes)	**Creativity:** Enhancing creativity and idea generation	2	2	2	2	1
	Change: Supporting positive change	1	1	1	0	0
		[56, 63, 96]	[56, 63, 96]	[56, 63, 96]	[40, 63]	[40]
Reflection (6 codes)	**Feedback:** Providing feedback to improve understanding and interaction	2	1	0	3	3
	Supportation: Supporting individual development and reflection	0	1	1	1	1
		[25, 95]	[5, 25]	[5]	[6, 19, 21, 95]	[6, 19, 21, 95]
Wise action (7 codes)	**Perspective-inclusive:** Recognising multiple perspectives for problem solving	0	1	1	1	0

SI factor	Description from the literature review	Design thinking phases addressing the definition Understanding users	Defining focus	Creating ideas	Generating prototypes	Testing with users
	Knowledge sharing: Supporting knowledge capturing and sharing	3	2	3	1	2
		[12, 25, 79]	[12, 17, 25]	[12, 17, 108]	[2, 12]	[12, 79]
Positive engagement (13 codes)	**Dynamics:** Supporting team dynamics and trust	6	2	3	0	2
	Communication and engagement: Enhancing emotional communication and engagement	2	2	1	2	1
	Initiation: Increasing participation, contribution and collaborative manners	1	2	0	1	0
		[3, 15, 39, 67, 71, 80, 98, 102, 114]	[4, 15, 54, 67, 71, 102]	[3, 54, 67, 80]	[16, 71, 114]	[67, 80, 114]
Effective responsivenes s (11 codes)	**Processes and methods:** Facilitating work with processes and methods	3	4	3	0	0
	Coordination: Coordinating teamwork and aligning interests	1	2	2	2	2
	Performance: Achieving common tasks	0	2	0	1	0
		[20, 28, 45, 81]	[4, 20, 28, 30, 45, 66, 81, 89]	[20, 28, 66, 81, 89]	[20, 66, 101]	[18, 66]

4.1.1 Systemic perception

All of the studies, including systemic perception elements, focused on expertise-related teamwork, such as students or work teams (13 papers). The target groups were technological or design-oriented [18, 20, 58], sales [79], biochemical [61], general work (e.g. [2, 71]) or collaborative teams combining both designers and engineers [68]. A variety of research and evaluation methods were used in the studies, including mixed methods (5 papers, e.g. [18, 33]), quantitative (2 papers [13, 26]) and qualitative methods (2 papers [71, 79]). Several studies included prototype generation or user tests (e.g. [2, 13, 18, 20]), and only one study focused merely on defining the focus phase [33]. Based on the analysis, two main themes summarise systemic perception factors.

Collaboration support: supporting collaboration and information sharing. Six papers [2, 20, 61, 68, 79, 82] discussed systemic perception from the aspect of collaboration support. Systemic perception includes an ability to take involved people and their interactions into account [37]. In practice, this is often considered as collaboration and information sharing between people involved in teamwork. It is in line with the literature review, as the findings described supportation of collaboration as helping people to work together, facilitating mutual understanding [61, 82] and supporting information sharing by providing tools to share content to improve collaboration and bridge barriers of sharing [68, 79]. To support collaboration, Reski et al. [82] investigated head-mounted displays in virtual reality teamwork. They proposed a hybrid asymmetric collaborative immersive analysis system for collaboration and investigated it with actual users. They found that the participants were 'very engaged in the activity itself as well as in the collaboration' [82]. For supporting information sharing, the Remote Solving workflow prototyped by Naugle and Roudsari [68] provides real-time feedback from an engineering point of view to enhance cross-disciplinary cooperation between designers and engineers. With the help of Remote Solving, teams can explore potential pattern designs and receive feedback on their performance by bridging practice barriers of information sharing within a multidisciplinary team [68].

Awareness: improving situation awareness and facilitating transparency. Seven papers [13, 18, 26, 33, 58, 71, 75] discussed systemic perception from the awareness viewpoint. As systemic perception highlights seeing and identifying different components within a system, between systems and being situationally aware [37], the findings within this category describe group members' awareness information tailored to the specific context and level of detail (e.g. activity, process, communication, context and availability issues) and facilitating team members to see contributions for tasks more transparently (e.g. [13, 18, 71, 75]). As an example of awareness, Crowston et al. [18] evaluated a stigmergic team coordination support system with user tests. They found out that by making individual contributions visible, the system was able to support awareness of coordination. In contrast, Poulovassilis and Xhafa [75] structured a P2P network model to provide awareness in project-based group work.

4.1.2 Attunement

Attunement (13 articles) was among the most addressed factors parallel with systemic perception and positive engagement factors. Mainly mixed (5 papers [6, 21, 29, 53, 114]) and quantitative (5 papers [54, 93, 100, 107, 111]) methods were used. One study [77] focused only on qualitative methods, and in two studies [16, 74], the research methodology was not available. There were articles focusing on each phase of design thinking, but most articles focused on prototype generation (7 papers) and user testing (6 papers). The attunement factor was researched in half of the papers that focused on families or close friends as their target group. Choi et al. [16] focused on couples living apart, and Yarosh et al. [114] researched divorced households, whereas other articles had a broader target group of non-work-related relationships [77, 107]. Two themes summarise attunement.

Behavioural signals: supportation for nonverbal and attentional behaviour. Eight studies focused on the behavioural signals perspective of the attunement factor [21, 29, 53, 54, 74, 93, 100, 111]. Attunement includes perceiving nonverbal communication and participating in social situations through, for instance, listening [37]. The focus of the findings was mainly on nonverbal signals and cues like visual attention and gaze coordination. Shimizu et al. [93] presented an audio-based support system focusing on attentional behaviour, which 'gives a passive participant a chance to take the next speaking turn by leading a mutual gaze' and 'triggers the passive participants' utterance'. Attentional behaviour appears in conversational turn-taking, when the current speaker looks at the next speaker, which typically means a signal that the turn to speak is given [93]. To support nonverbal behaviour, Li et al. [53] developed the OmniGlobeVR tool for collaboration between a VR user and multiple non-VR users. The tool includes a feature allowing non-VR users to share facial expressions, gaze and gestures with a VR-user for exchanging and expressing information with nonverbal cues [53].

Emotions: sharing emotions and communicating closeness. Attunement relates to being present and open, empathetic and attentive to others' experiences of a situation [37]. The findings revealed a gap in the notions of emotion sharing and closeness communication from work situations. Five studies focused on emotions, and only one of those focused on the work environment [6], whereas others focused on families or close friends [16, 77, 107, 114]. The only work environment-related article was written by Benke et al. [6], focusing on remote work teams with a limited capacity to transfer emotional information. They evaluated a retrospective emotional competence development system, TeamSpiritous, and showed a significant increase in intra- and interpersonal emotional competence [6]. For sharing emotions and communicating closeness, Choi et al. [16] investigated how a 'mini-hug' system called Ring*U 'can convey people's intimacy and emotional communication messages through subtle lighting and tactile expressions'. The article written by Yarosh et al. [114] presented the ShareTable, including a video chat opportunity and a shared tabletop task space. In the user test phase, divorced families used it to share emotional moments and communicate closeness with a metaphorical touch [114].

4.1.3 Positive attitude

The SI factor of positive attitude was among the least studied factors (6 publications). Three studies focused on family or close friends. In Vacca's [109] article, the target group was Latina teens and their caregivers. Ma et al. [56] examined long-distance couples, whereas Pradana and Buchanan [77] had no specific target group detailed. All three articles were conducted with qualitative methods (e.g. interview or observation). The rest of the findings targeted study or work teams. Most articles used qualitative methods, as there were only two [28, 69], including quantitative methods like questionnaires. Three main themes summarise the positive attitude factor.

Discussion: improving open dialogue and discussion. Three papers [19, 69, 109] focused on positive attitude from a discussion perspective. Positive attitude highlights situations, people and systems in an open way [37]. Related to this definition, the findings encouraged open discussion, communication and socialisation [19, 69, 109]. Only two articles included the final phases of design thinking (generating prototypes and testing with users [19, 109]). To improve openness between participants, Vacca [109] used participatory design methods with Latina teens and co-designed a tool called MomChill to improve teen-caregiver communication for a more positive perspective. This article included all five phases of design thinking [109]. To support socialisation within a team and facilitate positive activities, Dagan and Isbister [19] presented the Robo-Shoe-Flies design implementation, which is a social wearable design that people could wear at the office. The device encourages people to socialise and initiate conversations [19].

Experiences: Supporting positivity and reducing negative experiences. Two papers [28, 56] concentrated on this theme. Positive attitude includes a positive outlook and not getting stuck on negative impressions [37], which is directly related to this theme. For reducing negative priming or fixation, Ez-zaouia and Carrillo [28] designed a process structuring to enhance group work, with results revealing that 'process structuring appeared to reduce inhibitory effects of group work'. To support positivity, Ma et al. [56] investigated mechanisms for turning technological breakages into icebreakers with a workshop design. These situations can lead to 'positive behavioural, emotional and relational change' [56].

Empathy: Providing empathy, validation and support. Only one paper [77] focused on the empathy elements of a positive attitude. As positive attitude includes approaching situations, people and systems from various perspectives, including the provision of empathy, validation and support [37], Pradana and Buchanan [77] developed a prototype called Human Tamagotchi, which is a wearable system to support visual cues of cheering for each other. The prototype is based on a Japanese expression, *Otsukaresama,* to express 'thoughts on empathy and appreciating someone's effort' [77]. Their Human Tamagotchi concept opened possibilities to provide empathy, validation and support, especially in the interpersonal regulation of emotions [77].

4.1.4 Spirited discovery

Spirited discovery was among the least investigated factors (6 papers). The article written by Ma et al. [56] was the only one targeting families or close friends in this category, as the others focused on organisational teams such as science and technology enterprises [14], decision-making processes [40], innovation talent teams [112] and engineering teams [63, 96]. Both quantitative and qualitative research methodologies were used in a somewhat balanced way as well as several evaluation measures were employed. Based on the literature review and analysis, two primary themes could be summarised from this factor.

Creativity: Enhancing creativity and idea generation. Creativity was implied in most of the articles related to the factor, as there were five articles [14, 40, 63, 96, 112] focusing on the enhancement of creativity or idea generation, as the definition of spirited discovery emphasises innovativeness and creativity [37]. For example, Sozo and Ogliari [96] concentrated on emotional stimuli for creativity to enhance idea generation, leading to innovations. They outlined a method to encourage design teams to include emotions in processes with the help of emotriggers [96]. This method helped in idea generation from the perspectives of quantity, quality, variety and novelty [96]. As an example of idea generation, Jaasma et al. [40] described the design process of the Blue Studio, which is an interactive space for ideation processes. In the Blue Studio, interactive and spatial interventions are used encouraging teams to use all their senses in exploring challenges for unexpected ideas [40].

Change: Supporting positive change. In addition to creativity, the definition of the spirited discovery factor includes embracement of change and a positive attitude towards it [37]. This was implied only in one finding, which was research investigated by Ma et al. [56]. Their goal was to derive tactics to leverage antifragility without affecting people's relationship with technology, which helps to elicit diverse sensorial experiences of presence that impact the perception of interpersonal relationships by supporting positive change [56].

4.1.5 Reflection

With spirited discovery and positive attitude, reflection was among the least studied factors (6 papers). Only one study targeted families or close friends as the target group was parent-children teams [95]. Four studies targeted organisational or student teams, in which Ehrlich and Cataldo [25] focused on software development teams and other studies targeted organisational teams from a more general perspective [6, 18, 20]. In the study of Baumer et al. [5], the target group was not available. In nearly all studies, mixed methods and versatile evaluation measures were utilised (e.g. interviews, questionnaires, log files and notes). Dagan and Isbister [19] used only qualitative research methodology. The cross-tabulation revealed that each design thinking phase was researched in at least one of the studies. Four studies included user tests [6, 19, 21, 95] and the same studies presented design implementations, which is more than half of the findings in this category. Two main themes can be summarised from this factor.

Feedback: Providing feedback to improve understanding and interaction. Reflection includes an ability to analyse and develop one's behaviour as well as consider the consequences of choices and actions [37]. In practice, this was implemented as provision of feedback to improve understanding and interaction [19, 21, 25, 95]. For improving understanding, Damian et al. [21] presented Logue as a prototype providing feedback on the presenter's speaking-related factors (e.g. openness and body energy). A head-mounted display gives visual feedback on the user's nonverbal behaviour using social signal processing technologies, which increases the user's understanding [21]. For feedback to improve interaction, Song et al. [95] proposed and evaluated the TalkLIME system, providing feedback for parents to develop parent-child communication in real-time with children who are having language development challenges. Their results highlighted that the system encouraged parents' daily interaction, and children using the system had a better initiation ratio than others [95].

Supportation: Supporting individual development and reflection. As an SI factor, reflection highlights the examination of one's behaviour, understanding factors guiding actions and aims to grow as a person [37]. In line with this definition, the findings included supportation for individual development and reflection (2 papers [5, 6]). To support individual development, Benke et al. [6] evaluated a retrospective emotional competence development system, TeamSpiritous. It analyses previous emotional processes from the meetings and provides support for the development of emotional competence [6]. Baumer et al. [5] concentrated on reflection from a more comprehensive level as they found out that most research describes reflection as an individual activity and found a gap in acknowledging reflection as a social activity.

4.1.6 Wise action

Seven articles addressed the SI factor of wise action, and none focused on families or close friends. In one study, the target group was not available [7], and others focused on organisational teams, such as software [25] and product development teams [108]. As in most of the other factors, the studies related to wise action were using mainly mixed methods. Despite this, Collins and Etemadidavan [17] had a different evaluation measure. Their study was quantitative and used agent-based simulation [17]. Design thinking phases were distributed relatively evenly as at least three papers were focusing on each phase and the article written by Castro and Barcellos [12] concerned all phases of design thinking. The two following themes from the literature review summarise the findings.

Perspective-inclusive: Recognising multiple perspectives for problem solving. Listening to others and considering good advice are critical elements in the SI factor of wise action [37]. This was implied in two papers [2, 17] as an ability to recognise multiple perspectives and be more perspective-inclusive than exclusive to solve problems. For obtaining multiple perspectives, Altamirano et al. [2] proposed a graphic interface for the creation of task flow diagrams in interaction with a collaborative web system. Real-time creation of diagrams proved to help teams to obtain diverse perspectives and experiences [2]. The other article focused on multiple viewpoints. Collins and Etemadidavan [17] investigated the effect of multiple team memberships on complex design projects. They found out that the success of finding a feasible design solution increased when more perspectives were included in the teamwork.

Knowledge sharing: Supporting knowledge capturing and sharing. Knowledge sharing ties to the SI factor of wise action as it entails persistent holistic development requiring acceptance of one's limitations and understanding that success might require other people as well [37]. Knowledge sharing was found in five reviewed articles [7, 12, 25, 79, 108]. To support capturing and sharing knowledge, the most recent study written by Castro and Barcellos [12] developed a tool called KTID. It assists designers in annotating information regarding design choices in design artefacts that are shared with stakeholders [12]. Ugurlu and Gerhart [108] emphasised knowledge transparency and effective knowledge sharing. They presented a concept of accessing knowledge throughout product development processes gathering implicit knowledge of experts and specialists to reduce resources for knowledge search [108].

4.1.7 Positive engagement

The reviewed articles reported multiple ways to support positive engagement in interdependent teamwork (13 studies). Eight studies targeted student or organisational teams [3, 15, 29, 39, 67, 71, 80, 102], such as teams dealing with business process modelling activities [29], clinical staff members [80] or cross-departmental medical teams [15]. Three studies showed families or close friends as their target group [16, 98, 114]. Yarosh et al. [114] had divorced families as a target group, whereas Choi et al. [16] concentrated on couples. Both papers addressed positive engagement as well as the SI factor of attunement. The third paper with this target group concentrated on families with primary school children [98]. Variation between research methodologies was higher than in the other factors. Three articles used only quantitative methods [4, 15, 54] and five only qualitative methods (e.g. [39, 80]). Furthermore, several researches in this category used exclusively one evaluation measure (e.g. [4, 15, 29]). The design thinking emphasis was predominantly in the initial phases such as in understanding users (9 studies) and defining focus (6 studies). Based on the analysis, three themes summarise the positive engagement factor.

Dynamics: Supporting team dynamics and trust. Six studies focused on supporting team dynamics and trust [3, 39, 67, 80, 98, 102], which ties to the factor's definition and includes acknowledging and encouraging others as well as positive interactive approaches to others [37]. For supporting team dynamics, Athavankar et al. [3] examined the effect of pattern language on a team's behaviour and performance. The study revealed that pattern language helped to negate adverse team dynamics and leveraged positive aspects of teamwork [3]. For supporting team trust, Randall-James and Head [80] investigated how sharing past experiences with a systemic exercise could nourish a sense of belonging and trust. The context where people were allowed to take risks and permission to share experiences was approved beforehand, proved to influence trust and belonging [80].

Communication and engagement: Enhancing emotional communication and engagement. Positive engagement includes emotional intelligence and encouraging others [37]. Four studies [15, 16, 54, 114] supported this by focusing on communication and engagement. The focus of the findings was on emotional interactions, interpretation of communication behaviour, conveying emotional communication, mediating relatedness and enhancing engagement. For enhancing emotional communication, Choi et al. [16] presented a design implementation of Ring*U mini-hugs conveying intimacy and emotional communication messages between couples living apart. For enhancing engagement, Cheng [15] researched the effect of organisational learning culture related to professional engagement. They found out that it supports resources of team members and enhances their engagement, with suggestions to emphasise systematic learning support in a team [15].

Initiation: Increasing participation, contribution and collaborative manners. Three papers [4, 29, 71] discussed positive engagement from the aspect of initiation. Positive engagement includes taking systemic leverage points and means into action successfully with a focus on the people, highlighting the best aspects of people to pursue common interests with a positive approach [37]. This was also visible in the review, as the findings described joint visual attention to increasing collaborative manners [29], combatting social loafing and motivation for contribution [71] and increasing participation [4]. For increasing initiation, O'Leary et al. [71] investigated a blockchain system's ability to monitor employees' contributions and streamline the recording of an individual's input into a group effort. Their focus was on cross-functional dispersed teams that have challenges with social loafing, and the proof of concept managed to increase transparency and combat social loafing in teams [71].

4.1.8 Effective responsiveness

In total, 11 articles implied effective responsiveness in the research. As the description of the factor focuses on effective thinking and actions towards the goal, it is coherent that nearly all articles implying the factor were targeted to organisational teams. For example, Reiners et al. [81] concentrated on joint engineering research teams, Kane et al. [45] on teams of healthcare professionals, and some articles addressed organisational teams on a more general level (e.g. [66, 89]). Mixed methodologies combining quantitative and qualitative methods were most used [18, 28, 29, 45]. Two papers used qualitative methods [66, 81], one paper used quantitative methods [4] and in four, the methodology was not available [20, 30, 89, 101]. All evaluation measures were utilised in at least one of the articles except none were using agent-based simulation. The majority of articles (8 papers) addressed defining the focus phase of design thinking (e.g. [4, 20]), whereas prototype generation and user tests were researched in the minority of the articles. Based on the review and analysis, three primary themes summarise the effective responsiveness factor.

Processes and methods: Facilitating work with processes and methods. Effective responsiveness is considered an effective utilisation of expertise, environment and systems for achieving goals as well as prioritising and executing tasks systematically [37]. Five studies of the review [28, 29, 45, 81, 89] focused on facilitating work with processes and methods which can be used as techniques for systematic task execution and using resources effectively. As an example of team processes, Seeber [89] argued that recommender systems should be used as facilitators in teams to impact team processes and effectiveness as those provide essential content and technical facilitation for teamwork. For facilitating work with methods, Kane et al. [45] proposed a communication method for patient management to support shared decision-making. They examined the development of shared visual display methods in multidisciplinary team meetings. They found out that the method combining discussions and visual communication has the potential to transform health services to be more efficient and effective [45].

Coordination: Coordinating teamwork and aligning interests. Effective responsiveness highlights conformity to purpose and effective utilisation of people’s skills to achieve a common outcome [37]. Three papers of the review back this up by supporting coordination to focus immediately on the task and results [18], aligning interests and moving towards a goal [20] and tracing and visualising activities to coordinate teamwork [66]. For coordinating teamwork, Muñoz-Alcántara et al. [66] developed an online collaboration system called Alice to reconfigure team member interactions into visualisations. With time-oriented visualisations, the system was able to provide overviews of rhythms and temporal relationships of activities, supporting the coordination of teamwork [66]. For aligning interests, Dalsgaard et al. [20] introduced boundary zones and emergent boundary objects to highlight stakeholders’ interests and move towards goals in collaborative design projects.

Performance: Achieving common tasks. Three findings [4, 30, 101] focused on the performance perspective of effective responsiveness. Effective responsiveness is about purposefulness and goal orientation [37], and the findings support this by focusing on achieving common tasks. The findings focused on collaborative skill correlation to group performance [4], the effect of appropriate tasks in order to give the best performance [101] and on shared environments to assist in achieving common tasks [30]. For supporting performance, Sun and Shen [101] presented a prototype of a service-oriented system called Teamwork as a Service, enabling a rational grouping mechanism allocating team members to tasks appropriate for them to succeed in the best possible manner. For achieving common tasks, García et al. [30] proposed a strategy to integrate specific interactions in interfaces to support the improvement of effectively accomplishing activities and goals.

4.2 Framework for Systems Intelligence in design for interdependent teams

The Framework for Systems Intelligence in design for interdependent teams summarises the results and is presented in Figure 3. In the results of this review, seven out of eight original SI factors are extended with HCI context-specific descriptions. Systemic perception focuses on seeing and identifying systems' components and includes situational awareness [37]. This was extended with practical ways of perceiving the system by supporting collaboration and information sharing (collaboration support). Attunement focuses on being open, empathetic and situationally sensitive [37], which in practice means sharing emotions. The factor is extended with the support provided for behavioural signals. Furthermore, this factor was mainly studied within families. Positive attitude covers attitudinal aspects of experiences by keeping a positive outlook and not getting stuck with negativity as well as a provision of empathy [37]. This is extended with discussion practices to improve open dialogue and socialisation (discussion). The previous definition of reflection focuses on individual perspectives, such as reflecting upon one's thinking and actions to support individual development [34]. Our findings extend it with the provision of feedback to improve understanding and interaction in interdependent teams. Wise action concentrates on exercising long-term thinking, realising implications and understanding that consequences take time to develop [37], which can be summarised as being perspective-inclusive. This is extended with knowledge sharing in human systems. Positive engagement is about taking along systemic leverage points and means successfully into action with people [37]. This factor is concretised by supporting team dynamics, enhancing emotional communication and engagement, and increasing participation, contribution and collaborative manners for initiation. Effective responsiveness is about taking systemic leverage points and means successfully into action with the environment, being able to dance with the system through effective utilisation of people's skills [37], which is summarised as coordination. Effective responsiveness also focuses on purposefulness and goal orientation [37], such as performance. The definition is extended with a perspective of facilitating work with processes and methods. The themes of spirited discovery (such as engaging new ideas and embracing change) were both supported by the findings of this review [36].

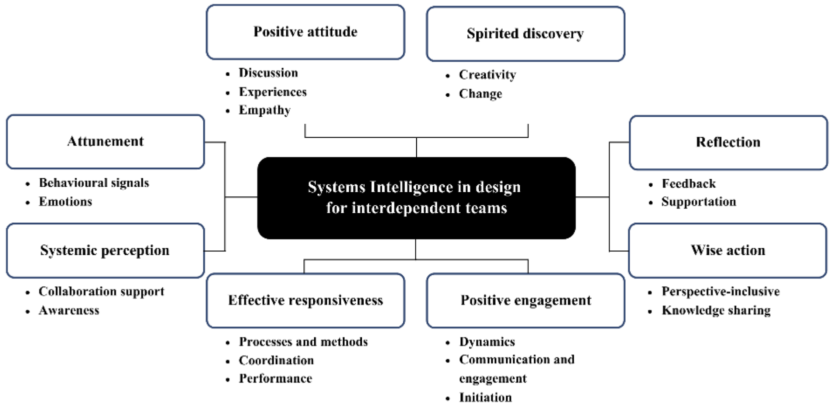

Figure 3: Framework for Systems Intelligence in design for interdependent teams.

5 DISCUSSION

The goal of this study was to construct a framework for SI design solutions supporting the teamwork of interdependent teams based on a systematic literature review. SI offered a multidisciplinary, theoretical and systems-oriented frame to explain intelligent behaviour in the context of complex systems (e.g. interdependent teams) involving feedback and interactions. A systematic literature review was conducted, and 57 publications were included in the review to summarise the research between the years 2013–2023. The results integrate previous research, build an understanding of design and construct a framework for design for SI of interdependent teams in HCI. The findings of this review showed that all eight SI factors were studied with heterogeneous teams, a variety of methods, in different phases of the design process and different types of outcomes. It provides evidence that SI exists in the design of interdependent teams in the context of HCI, although its terminology was not explicitly stated in the literature. The results give further support to systemic design approaches in which overarching design methodologies often involve applying systems thinking modes and theories within design contexts to facilitate a more profound comprehension and propose design decisions aimed at high-impact interventions [41]. Given its broad array of transdisciplinary and theoretical influences, systemic design benefits from a diverse range of methods in its applications [41].

5.1 Enhancements of SI in the HCI context

This study's findings were summarised as a framework for SI in design for interdependent teams (Figure 3). As a means to define what design for SI in interdependent teams is, the results are not only in line with original definitions of SI factors but also extend them (seven out of eight factors). These extensions are HCI context-specific and reflect practices to support system, collaboration and interaction in design for interdependent teams. The enhancements bring SI from universal perspectives to the local everyday life of designing for interdependent teams and to HCI. In previous research, context-specific enhancements of SI have been reported in organisational development and art leadership [46, 47]. In the design context, the framework responds to the need to see systemic design as situated, pluralistic and focusing on the everyday nature of design practices [110]. The findings of our study also showed that the focus on SI factors varied depending on the characteristics of teams and the phases of the design process. Organisational (e.g. engineering, design, healthcare) and student teams were more often studied than groups with tight social connections. Three factors, named systemic perception, wise action and effective responsiveness, were only studied with organisational or student teams. In contrast, attunement, positive attitude and positive engagement factors were also studied with families or close friends (3–4 papers each per factor). Furthermore, the study's results showed that positive attitude, positive engagement, spirited discovery and effective responsiveness were studied in the early design phases of understanding users and defining requirements rather than later phases of prototyping and user testing which were focused on studies with systemic perception, reflection and attunement.

5.2 Application of the SI framework in design practices

The framework presented can be utilised in design practices when designing for SI of interdependent teams and it can be extended in future work. The current framework makes a theoretical and meta-analysis contribution to inter- and multidisciplinary HCI [113]. As a descriptive framework, it brings novelty to a topic by distilling the main aspects of the SI factors in interdependent teams of the HCI context. In order to ensure practical implementation, it should be aligned with human-centred design principles as outlined in the ISO 9241-210 standard [117]. By integrating the SI framework and all SI factors into this process, designers can create user-centred solutions that effectively support SI in interdependent teams. This responds to the need to focus on broader implications with design beyond UX and functionality [8, 97] as well as making SI explicit. One preliminary study has taken steps towards applying SI in design practices by combining SI in empathic design and evaluation [44] without a systematic focus on all phases of the design process. In practice, this would require the adaptation of old or the development of new design tactics, tools, methods or practices to support designers' work. In the early design phase of constructing an understanding of users and the context of use, the framework can enrich user research with themes, e.g. in interviews and observations. When defining the requirements it can inform setting the user experience goals. In ideation, the framework can provide themes for brainstorming with SI's perspective. In prototyping, it can be used to support designers' work as a guideline and applied to develop SI-enhancing features in prototypes. Finally in evaluation, it can be further developed as a tool for expert evaluation or a survey for user research. Testing the SI-focused prototypes with real users and gathering feedback through user testing sessions can help refine the features and validate their impact on team dynamics. The framework can be developed towards expert methods (e.g. heuristic evaluation tool [92]) to support assessment.

The study establishes a foundation for applying the SI framework in practice, but further work is needed to explore its practical implementation. Future work is needed to develop the framework to guide system design for interdependent teams, evaluate the importance of each factor and test it in real-world settings. Applying the framework in diverse industries or contexts, such as work or leisure, is crucial to demonstrating its applicability. The framework has the potential to enhance interaction and collaboration across various fields. For example, wearable technology has been used to mediate socially connected team dynamics [27, 65], and testing it in similar situations would be valuable. In healthcare, where precision and collaboration are vital, the framework could be used to improve team dynamics, communication and coordination, as well as non-technological aspects of interaction, fostering better decision-making. Aligning the framework with healthcare professionals' needs, like how systems thinking has been integrated into trauma-response teams [62] or collective intelligence into clinical settings [78], would further demonstrate its applicability. In engineering and design, the framework could guide the development of both digital and non-digital tools for better teamwork across distributed teams or enhance face-to-face collaboration. As remote work becomes more common, improving systems intelligence in teams through digital platforms could boost project outcomes and innovation, like how wearable technology has been used to improve design teams [94]. In education, the framework could be applied to design tools that foster student collaboration on group projects or to improve communication strategies among school management or teacher teams, leading to better alignment of goals, needs and wellbeing. A recent study has already shown a connection between systems intelligence and occupational wellbeing among early childhood education professionals [51].

5.3 Limitations of the study

There are four main limitations in this study. Firstly, a systematic review method including specific filtering and selection strategies in a selected timeframe to study design for SI in interdependent teams was used [70]. The limitation of this method is incomplete as it does not cover all relevant publication forums and articles in the same time frame. Secondly, the search in the databases was limited to articles published between 2013–2023. This period has its own everyday life (incl. pandemic time), design and research practices and technology, which are reflected in the data and results. Thirdly, SI is a new concept in the design context, and it was rather implicitly than explicitly described in data, as also stated in [47], meaning that SI was not clearly mentioned as a term but rather referenced or inferred through context or examples. This was manifested using SI factors and definitions suggesting SI without directly mentioning the concept. Fourthly, the findings in this literature review primarily focus on organisational and student teams, which may limit their generalisability to other types of interdependent teams. Even though the thematic analysis with reliability analysis was conducted, there may be bias in the interpretation of data.

5.4 Future research

Future research needs to focus on bringing this theoretically oriented framework to designers' practice, approaching teams holistically and approaching systems as a dynamic whole in design. Previous research has reported that successful teams perform well in both taskwork as completing the specific tasks to achieve team goals and teamwork as shared behaviours, attitudes and cognitions [87]. Taskwork-related aspects such as performance and effectiveness have been paid more attention than the holistic perspectives of a team [60]. Similarly, in our review, the current design focused mainly on supporting the taskwork of the team (e.g. performance, status) while there was a gap in designing for teamwork. Future research is needed to support holistically both taskwork and teamwork with our framework when designing technology to support interdependent teams. It should delve into the dynamic and relational aspects of SI in team design, mainly through longitudinal studies. Examining the long-term effects of SI-focused design interventions could provide valuable insights into how SI evolves within teams over time and how it influences sustained performance and teamwork.

As the review can be generalised mainly to organisational and student teams, future research could expand the analysis to include family teams, sports teams and volunteer groups to assess the applicability of the SI framework in these different contexts. This could provide a more comprehensive understanding of how SI principles apply to various team dynamics. Finally, further work needs to extend this framework with relational and dynamic aspects of the systemic whole. Our framework gives a modular or static description of SI factors when designing for interdependent teams in HCI. However, systems are whole, dynamic and relational [10, 37, 84, 90, 110]. A system's performance depends more on how its parts interact than on how they act independently of each other [10]. Systemic design is an ongoing process where we are engaged in designing ourselves, people and the world around us [1]. By understanding the relations between the SI factors and designers' work within systems, we can theoretically and practically approach more richly the improvement of systems we are designing for in the context of HCI.

6 CONCLUSION

This study's systematic literature review of 57 high-quality research publications between the years 2013–2023 revealed three main conclusions. SI is an existing phenomenon in design for interdependent teams in the context of human-computer interaction, although it was somewhat alluded to rather than explicitly stated. The results as a framework of Systems Intelligence in design for interdependent teams are summarised with eight factors and context-specific extensions. Emphasis on different factors was influenced by the studied teams and the phase of the design process. Future work needs to 1) make SI explicit and integrate our framework throughout the design process when designing for flourishing interdependent teams in HCI, 2) approach interdependent teams holistically and 3) extend our framework with relational and dynamic aspects of the systemic whole in design.

REFERENCES

[1] Yoko Akama and Alison Prendiville. 2014. Embodying, enacting and entangling design: a phenomenological view to co-designing services. *Swedish Design Research Journal* 1, (January 2014), 29–40.

[2] Harim Castellanos Altamirano, Carlos Alberto Fernández-y-Fernández, and José Figueroa Martínez. 2014. Modeling a web interface for creating task flow diagrams through interaction with a collaborative system. In *Proceedings of the 5th Mexican Conference on Human-Computer Interaction*, November 03, 2014. ACM, Oaxaca Mexico Mexico, 7–10. https://doi.org/10.1145/2676690.2676695

[3] Uday Athavankar, Pramod Khambete, Debjani Roy, Sujata Chaudhary, Sanjay Kimbahune, Pankaj Doke, and Sujit Devkar. 2014. Multidisciplinary Team Dynamics in Service Design- The Facilitating Role of Pattern Language. In *Proceedings of the India HCI 2014 Conference on Human Computer Interaction - IHCI '14*, 2014. ACM Press, New Delhi, India, 16–25. https://doi.org/10.1145/2676702.2676703

[4] Aaron Bauer and Zoran Popović. 2017. Collaborative Problem Solving in an Open-Ended Scientific Discovery Game. *Proc. ACM Hum.-Comput. Interact.* 1, CSCW (December 2017), 1–21. https://doi.org/10.1145/3134657

[5] Eric P.S. Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, and Geri Gay. 2014. Reviewing reflection: on the use of reflection in interactive system design. In *Proceedings of the 2014 conference on Designing interactive systems*, June 21, 2014. ACM, Vancouver BC Canada, 93–102. https://doi.org/10.1145/2598510.2598598

[6] Ivo Benke, Maren Schneider, Xuanhui Liu, and Alexander Maedche. 2022. TeamSpiritous - A Retrospective Emotional Competence Development System for Video-Meetings. *Proc. ACM Hum.-Comput. Interact.* 6, CSCW2 (November 2022), 1–28. https://doi.org/10.1145/3555117

[7] Beatrice Biancardi, Lou Maisonnave-Couterou, Pierrick Renault, Brian Ravenet, Maurizio Mancini, and Giovanna Varni. 2020. The WoNoWa Dataset: Investigating the Transactive Memory System in Small Group Interactions. In *Proceedings of the 2020 International Conference on Multimodal Interaction*, October 21, 2020. ACM, Virtual Event Netherlands, 528–537. https://doi.org/10.1145/3382507.3418843

[8] Simon Bibri. 2015. *The Human Face of Ambient Intelligence: Cognitive, Emotional, Affective, Behavioral and Conversational Aspects*. https://doi.org/10.2991/978-94-6239-130-7

[9] Julie T. Bidwell, Catherine Conway, Viktoriya Babicheva, and Christopher S. Lee. 2023. Person with Heart Failure and Care Partner Dyads: Current Knowledge, Challenges, and Future Directions: State-of-the-Art Review. *Journal of Cardiac Failure* 29, 8 (August 2023), 1187–1206. https://doi.org/10.1016/j.cardfail.2023.02.017

[10] Mieke van der Bijl-Brouwer. 2017. Designing for Social Infrastructures in Complex Service Systems: A Human-Centered and Social Systems Perspective on Service Design. *She Ji: The Journal of Design, Economics, and Innovation* 3, 3 (September 2017), 183–197. https://doi.org/10.1016/j.sheji.2017.11.002

[11] Virginia Braun and Victoria Clarke. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology* 3, 2 (January 2006), 77–101. https://doi.org/10.1191/1478088706qp063oa

[12] Murillo Castro and Monalessa Barcellos. 2022. An Ontology to support Knowledge Management Solutions for Human-Computer Interaction Design. In *Proceedings of the XXI Brazilian Symposium on Software Quality*, November 07, 2022. ACM, Curitiba Brazil, 1–

10. https://doi.org/10.1145/3571473.3571502

[13] Y.-L. Betty Chang, Stacey D. Scott, and Mark Hancock. 2014. Supporting Situation Awareness in Collaborative Tabletop Systems with Automation. In *Proceedings of the Ninth ACM International Conference on Interactive Tabletops and Surfaces*, November 16, 2014. ACM, Dresden Germany, 185–194. https://doi.org/10.1145/2669485.2669496

[14] Qinxian Chen and Saipeng Xing. 2022. Promotion Path of R & D Team Creativity in Chinese Science and Technology Enterprises in the Era of Artificial Intelligence. In *2022 3rd International Conference on Education Development and Studies*, March 09, 2022. ACM, Hilo HI USA, 146–151. https://doi.org/10.1145/3528137.3528162

[15] Fang Cheng. 2020. Research on the Influence of Organizational Learning Culture on the Engagement of Cross-departmental team Members: Taking a chronic disease management team of an integrated medical service organization in Beijing as an example. In *Proceedings of the 2020 3rd International Conference on E-Business, Information Management and Computer Science*, December 05, 2020. ACM, Wuhan China, 504–512. https://doi.org/10.1145/3453187.3453386

[16] Yongsoon Choi, Jordan Tewell, Yukihiro Morisawa, Gilang A. Pradana, and Adrian David Cheok. 2014. Ring*U: a wearable system for intimate communication using tactile lighting expressions. In *Proceedings of the 11th Conference on Advances in Computer Entertainment Technology*, November 11, 2014. ACM, Funchal Portugal, 1–4. https://doi.org/10.1145/2663806.2663814

[17] Andrew J. Collins and Sheida Etemadidavan. 2022. A Hybrid Model of Multiple Team Membership and Its Impacts on System Design. In *2022 Winter Simulation Conference (WSC)*, December 11, 2022. IEEE, Singapore, 1–11. https://doi.org/10.1109/WSC57314.2022.10015231

[18] Kevin Crowston, Jeffery Saltz, Niraj Sitaula, and Yatish Hegde. 2021. Evaluating MIDST, A System to Support Stigmergic Team Coordination. *Proc. ACM Hum.-Comput. Interact.* 5, CSCW1 (April 2021), 1–24. https://doi.org/10.1145/3449110

[19] Ella Dagan and Katherine Isbister. 2021. Synergistic Social Technology: Designing Systems with 'Needs' that Encourage and Support Social Interaction. In *Designing Interactive Systems Conference 2021*, June 28, 2021. ACM, Virtual Event USA, 1419–1432. https://doi.org/10.1145/3461778.3462021

[20] Peter Dalsgaard, Kim Halskov, and Ditte Amund Basballe. 2014. Emergent boundary objects and boundary zones in collaborative design research projects. In *Proceedings of the 2014 conference on Designing interactive systems*, June 21, 2014. ACM, Vancouver BC Canada, 745–754. https://doi.org/10.1145/2598510.2600878

[21] Ionut Damian, Chiew Seng (Sean) Tan, Tobias Baur, Johannes Schöning, Kris Luyten, and Elisabeth André. 2015. Augmenting Social Interactions: Realtime Behavioural Feedback using Social Signal Processing Techniques. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*, April 18, 2015. ACM, Seoul Republic of Korea, 565–574. https://doi.org/10.1145/2702123.2702314

[22] Mahboobeh Davaei and Marjaana Gunkel. 2024. The role of intelligences in teams: a systematic literature review. *Rev Manag Sci* 18, 1 (January 2024), 259–297. https://doi.org/10.1007/s11846-023-00672-7

[23] Kelley E. Dugan, Erika A. Mosyjowski, Shanna R. Daly, and Lisa R. Lattuca. 2022. Systems thinking assessments in engineering: A systematic literature review. *Systems Research and Behavioral Science* 39, 4 (2022), 840–866. https://doi.org/10.1002/sres.2808

[24] Abigail C. Durrant, John Vines, Jayne Wallace, and Joyce S. R. Yee. 2017. Research Through Design: Twenty-First Century Makers and Materialities. *Design Issues* 33, 3 (July 2017), 3–10. https://doi.org/10.1162/DESI_a_00447

[25] Kate Ehrlich and Marcelo Cataldo. 2014. The Communication Patterns of Technical Leaders: Impact on Product Development Team Performance. February 15, 2014. . https://doi.org/10.1145/2531602.2531671

[26] Lucca Eloy, Cara Spencer, Emily Doherty, and Leanne Hirshfield. 2023. Capturing the Dynamics of Trust and Team Processes in Human-Human-Agent Teams via Multidimensional Neural Recurrence Analyses. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW1 (April 2023), 1–23. https://doi.org/10.1145/3579598

[27] Andrey Esakia, Scott McCrickard, Samantha Harden, Michael Horning, Nithyapriya Ramalingam, and Virginia Tech. 2020. Using Smartwatches to Facilitate a Group Dynamics-Based Statewide Physical Activity Intervention. *International Journal of Human-Computer Studies* 142, (June 2020), 102501. https://doi.org/10.1016/j.ijhcs.2020.102501

[28] Mohamed Ez-zaouia and Rubiela Carrillo. 2023. The Group Folding Effect: The Role of Collaborative Process Structuring and Social Interaction in Group Work. *ACM Trans. Comput.-Hum. Interact.* (September 2023), 3622783. https://doi.org/10.1145/3622783

[29] Duygu Fındık-Coşkunçay and Murat Perit Çakır. 2022. An investigation of the relationship between joint visual attention and product quality in collaborative business process modeling: a dual eye-tracking study. *Softw Syst Model* 21, 6 (December 2022), 2429–2460. https://doi.org/10.1007/s10270-022-00974-6

[30] Huizilopoztli Luna García, Ricardo Mendoza González, Miguel Vargas Martin, Jaime Muñoz Arteaga, Francisco J. Álvarez Rodríguez, and Laura C. Rodríguez Martínez. 2014. A Classification of Design Patterns to Support Mobile Groupware Systems. In *Proceedings of the 5th Mexican Conference on Human-Computer Interaction*, November 03, 2014. ACM, Oaxaca Mexico Mexico, 46–52. https://doi.org/10.1145/2676690.2676691

[31] Eleni Georganta, Claudia Peus, and Jasmin Niess. 2023. Interactive technologies through the lens of team effectiveness: an interdisciplinary systematic literature review. *European Journal of Work and Organizational Psychology* 0, 0 (2023), 1–16. https://doi.org/10.1080/1359432X.2023.2178904

[32] Elisa Giaccardi. 2019. Histories and Futures of Research through Design: From Prototypes to Connected Things. *International Journal of Design* 13, 3 (2019), 155.

[33] Michael Gilbert and Mark Zachry. 2015. Tool-mediated coordination of virtual teams in complex systems. In *Proceedings of the 11th International Symposium on Open Collaboration*, August 19, 2015. ACM, San Francisco California, 1–8.

https://doi.org/10.1145/2788993.2789843

[34] Daniel Goleman. 1999. *Working with emotional intelligence*. Bantam books, New York.

[35] Daniel J. Griffin, Ajay V. Somaraju, Christopher Dishop, and Richard P. DeShon. 2023. Evaluating Interdependence in Workgroups: A Network-Based Method. *Organizational Research Methods* 26, 3 (July 2023), 459–498. https://doi.org/10.1177/10944281211068179

[36] Stanley M. Gully, Kara A. Incalcaterra, Aparna Joshi, and J. Matthew Beauien. 2002. A meta-analysis of team-efficacy, potency, and performance: interdependence and level of analysis as moderators of observed relationships. *J Appl Psychol* 87, 5 (October 2002), 819–832. https://doi.org/10.1037/0021-9010.87.5.819

[37] Raimo P. Hämäläinen, Rachel Jones, and Esa Saarinen. 2014. *Being Better Better - Living with Systems Intelligence*. Crossover, Helsinki, Finland. Retrieved January 6, 2024 from http://systemsintelligence.aalto.fi/being_better_better/

[38] Raimo P. Hämäläinen and Esa Saarinen. 2007. Systems Intelligence: A Key Competence in Human Action and Organizational Life. In *Systems Intelligence in Leadership and Everyday Life*. Helsinki University of Technology, Espoo, 39–50.

[39] Regina Hebig and Jesper Derehag. 2016. How do process and team interaction depend on development technologies?: a case study on a combined setting of model-driven development and classical C coding. In *Proceedings of the International Conference on Software and Systems Process*, May 14, 2016. ACM, Austin Texas, 16–25. https://doi.org/10.1145/2904354.2904366

[40] Philemonne Jaasma, Dorothé Smit, Jelle Van Dijk, Thomas Latcham, Ambra Trotto, and Caroline Hummels. 2017. The Blue Studio: Designing an Interactive Environment for Embodied Multi-Stakeholder Ideation Processes. In *Proceedings of the Eleventh International Conference on Tangible, Embedded, and Embodied Interaction*, March 20, 2017. ACM, Yokohama Japan, 1–10. https://doi.org/10.1145/3024969.3025002

[41] Peter Jones. 2021. Systemic Design: Design for Complex, Social, and Sociotechnical Systems. In *Handbook of Systems Sciences*, Gary S. Metcalf, Kyoichi Kijima and Hiroshi Deguchi (eds.). Springer, Singapore, 787–811. https://doi.org/10.1007/978-981-15-0720-5_60

[42] Peter Jones and Kristel Van Ael. 2022. *Design Journeys Through Complex Systems: Practice Tools for Systemic Design*. BIS Publishers.

[43] Peter H. Jones. 2014. Systemic Design Principles for Complex Social Systems. In *Social Systems and Design*, Gary S. Metcalf (ed.). Springer Japan, Tokyo, 91–128. https://doi.org/10.1007/978-4-431-54478-4_4

[44] Satu Jumisko-Pyykkö, Teemu Viita-aho, Eero Tiilikainen, and Esa Saarinen. 2021. Towards Systems Intelligent Approach in Empathic Design. In *Proceedings of the 24th International Academic Mindtrek Conference* (*Academic Mindtrek '21*), September 07, 2021. Association for Computing Machinery, New York, NY, USA, 197–209. https://doi.org/10.1145/3464327.3464370

[45] Bridget T. Kane, Pieter J. Toussaint, and Saturnino Luz. 2013. Shared decision making needs a communication record. In *Proceedings of the 2013 conference on Computer supported cooperative work*, February 23, 2013. ACM, San Antonio Texas USA, 79–90. https://doi.org/10.1145/2441776.2441788

[46] Jari Kautiala, Satu Jumisko-Pyykkö, Raimo P. Hämäläinen, and Esa Saarinen. 2024. Systems Intelligence in an Expert Organization: A Mixed Methods Approach. *Proceedings of AHFE (International Conference on Applied Human Factors and Ergonomics)* (2024).

[47] Kate Preston Keeney and Yuha Jung. 2023. Hidden in Plain Sight: Systems Intelligence in Arts Leadership. *The Journal of Arts Management, Law, and Society* 53, 1 (January 2023), 1–18. https://doi.org/10.1080/10632921.2022.2080138

[48] Ilpo Koskinen, John Zimmerman, Thomas Binder, Johan Redström, and Stephan Wensveen. 2012. *Design Research Through Practice*. Elsevier. https://doi.org/10.1016/C2010-0-65896-2

[49] Steve W.J. Kozlowski and Daniel R. Ilgen. 2006. Enhancing the Effectiveness of Work Groups and Teams. *Psychol Sci Public Interest* 7, 3 (December 2006), 77–124. https://doi.org/10.1111/j.1529-1006.2006.00030.x

[50] Peter Gall Krogh and Ilpo Koskinen. 2022. How Constructive Design Researchers Drift: Four Epistemologies. *Design Issues* 38, 2 (April 2022), 33–46. https://doi.org/10.1162/desi_a_00680

[51] Kata-Riikka Kumpulainen, Nina Sajaniemi, Eira Suhonen, and Harri Pitkäniemi. 2023. Occupational well-being and teamwork in Finnish early childhood education. *Journal of Early Childhood Education Research* 12, 2 (April 2023), 71–97. https://doi.org/10.58955/jecer.v12i2.119784

[52] Jung-Joo Lee. 2012. *Against Method: The Portability of Method in Human-Centered Design*. Aalto University. Retrieved April 9, 2024 from https://aaltodoc.aalto.fi/handle/123456789/11461

[53] Zhengqing Li, Liwei Chan, Theophilus Teo, and Hideki Koike. 2020. OmniGlobeVR: A Collaborative 360° Communication System for VR. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, April 25, 2020. ACM, Honolulu HI USA, 1–8. https://doi.org/10.1145/3334480.3382869

[54] Yun-Shao Lin, Yi-Ching Liu, and Chi-Chun Lee. 2023. An Interaction-process-guided Framework for Small-group Performance Prediction. *ACM Trans. Multimedia Comput. Commun. Appl.* 19, 2 (May 2023), 1–25. https://doi.org/10.1145/3558768

[55] Jukka Luoma, Raimo P. Hämäläinen, and Esa Saarinen. 2008. Perspectives on team dynamics: Meta learning and systems intelligence. *Systems Research and Behavioral Science* 25, 6 (2008), 757–767. https://doi.org/10.1002/sres.905

[56] Xiaojuan Ma, Ke Fang, and Fengyuan Zhu. 2016. From Breakage to Icebreaker: Inspiration for Designing Technological Support for Human-Human Interaction. In *Proceedings of the 2016 ACM Conference on Designing Interactive Systems*, June 04, 2016. ACM, Brisbane QLD Australia, 403–414. https://doi.org/10.1145/2901790.2901800

[57] Ray Maher, Melanie Maher, Samuel Mann, and Clive A. McAlpine. 2018. Integrating design thinking with sustainability science: a Research through Design approach. *Sustain Sci* 13, 6 (November 2018), 1565–1587. https://doi.org/10.1007/s11625-018-0618-6

[58] Elena Maris, Kelly B. Wagman, Rachel Bergmann, and Danielle Bragg. 2023. Tech Worker Perspectives on Considering the Interpersonal

Implications of Communication Technologies. *Proc. ACM Hum.-Comput. Interact.* 7, GROUP (January 2023), 1–22. https://doi.org/10.1145/3567566

[59] Frank Martela and Esa Saarinen. 2013. The Systems Metaphor in Therapy Discourse: Introducing Systems Intelligence. *Psychoanalytic Dialogues* 23, (February 2013). https://doi.org/10.1080/10481885.2013.754281

[60] John Mathieu, M. Travis Maynard, Tammy Rapp, and Lucy Gilson. 2008. Team Effectiveness 1997-2007: A Review of Recent Advancements and a Glimpse Into the Future. *Journal of Management* 34, 3 (June 2008), 410–476. https://doi.org/10.1177/0149206308316061

[61] Meghna Mehta, Ahmed Sabbir Arif, Apurva Gupta, Sean DeLong, Roozbeh Manshaei, Graceline Williams, Manasvi Lalwani, Sanjay Chandrasekharan, and Ali Mazalek. 2016. Active Pathways: Using Active Tangibles and Interactive Tabletops for Collaborative Modeling in Systems Biology. In *Proceedings of the 2016 ACM International Conference on Interactive Surfaces and Spaces*, November 06, 2016. ACM, Niagara Falls Ontario Canada, 129–138. https://doi.org/10.1145/2992154.2992176

[62] Tai J. Mendenhall and Jerica M. Berge. 2010. Family therapists in trauma-response teams: Bringing systems thinking into interdisciplinary fieldwork. *Journal of Family Therapy* 32, 1 (2010), 43–57. https://doi.org/10.1111/j.1467-6427.2009.00482.x

[63] Matthias Merk, Gabriela Tullius, and Peter Hertkorn. 2017. Collaboration and Creativity Support for Interdisciplinary Engineering Teams Using Component Based Systems and Cognitive Services. In *Cooperative Design, Visualization, and Engineering* (*Lecture Notes in Computer Science*), 2017. Springer International Publishing, Cham, 177–184. https://doi.org/10.1007/978-3-319-66805-5_22

[64] Pietro Micheli, Sarah Wilner, Sabeen Bhatti, Matteo Mura, and Michael Beverland. 2018. Doing Design Thinking: Conceptual Review, Synthesis and Research Agenda. *Journal of Product Innovation Management* 36, (August 2018). https://doi.org/10.1111/jpim.12466

[65] Alessandro Montanari. 2019. Devising and evaluating wearable technology for social dynamics monitoring. (May 2019). https://doi.org/10.17863/CAM.39687

[66] Jesús Muñoz-Alcántara, Ruslan Kreymer, Mathias Funk, and Panos Markopoulos. 2018. Alice: design of a Time-oriented Collaboration Service for Design Teams. In *Proceedings of the ACM SIGCHI Symposium on Engineering Interactive Computing Systems*, June 19, 2018. ACM, Paris France, 1–6. https://doi.org/10.1145/3220134.3220143

[67] Geoff Musick, Elizabeth S. Gilman, Wen Duan, Nathan J. McNeese, Bart Knijnenburg, and Thomas O'Neill. 2023. Knowing Unknown Teammates: Exploring Anonymity and Explanations in a Teammate Information-Sharing Recommender System. *Proc. ACM Hum.-Comput. Interact.* 7, CSCW2 (September 2023), 1–34. https://doi.org/10.1145/3610075

[68] Matthew R. Naugle and Mostapha Roudsari. 2015. Remote solving: A methodological shift in collaborative building design and analysis. In *Proceedings of the Symposium on Simulation for Architecture & Urban Design* (*SimAUD '15*), April 12, 2015. Society for Computer Simulation International, San Diego, CA, USA, 28–34.

[69] Duyen T. Nguyen and Susan R. Fussell. 2013. Effect of message content on communication processes in intercultural and same-culture instant messaging conversations. In *Proceedings of the 2013 conference on Computer supported cooperative work*, February 23, 2013. ACM, San Antonio Texas USA, 19–32. https://doi.org/10.1145/2441776.2441782

[70] Chitu Okoli. 2015. A Guide to Conducting a Standalone Systematic Literature Review. *Communications of the Association for Information Systems* 37, (November 2015). https://doi.org/10.17705/1CAIS.03743

[71] Kevin O'Leary, Philip O'Reilly, Joseph Feller, Rob Gleasure, Shanping Li, and Jerry Cristoforo. 2017. Exploring the Application of Blockchain Technology to Combat the Effects of Social Loafing in Cross Functional Group Projects. In *Proceedings of the 13th International Symposium on Open Collaboration*, August 23, 2017. ACM, Galway Ireland, 1–8. https://doi.org/10.1145/3125433.3125464

[72] Erin Peavey and Hui Cai. 2020. A Systems Framework for Understanding the Environment's Relation to Clinical Teamwork: A Systematic Literature Review of Empirical Studies. *Environment and Behavior* 52, 7 (August 2020), 726–760. https://doi.org/10.1177/0013916518815535

[73] Anthony T. Pescosolido and Richard Saavedra. 2012. Cohesion and Sports Teams: A Review. *Small Group Research* 43, 6 (December 2012), 744–758. https://doi.org/10.1177/1046496412465020

[74] Erik Poppe, Ross Brown, Jan Recker, and Daniel Johnson. 2013. Improving Remote Collaborative Process Modelling using Embodiment in 3D Virtual Environments. January 01, 2013. .

[75] Alexandra Poulovassilis and Fatos Xhafa. 2013. Building Event-Based Services for Awareness in P2P Groupware Systems. In *2013 Eighth International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, October 2013. IEEE, COMPIEGNE, France, 200–207. https://doi.org/10.1109/3PGCIC.2013.36

[76] John Pourdehnad, Dennis Wilson, and Erica Wexler. 2011. Systems & Design Thinking: A Conceptual Framework for Their Integration. *Proceedings of the 55th Annual Meeting of the ISSS - 2011, Hull, UK* (September 2011). Retrieved April 13, 2024 from https://journals.isss.org/index.php/proceedings55th/article/view/1650

[77] Gilang Andi Pradana and George Buchanan. 2017. Imparting Otsukaresama: Designing Technology to Support Interpersonal Emotion Regulation. In *Proceedings of the 3rd International Conference on Human-Computer Interaction and User Experience in Indonesia*, April 18, 2017. ACM, Jakarta Indonesia, 34–43. https://doi.org/10.1145/3077343.3077347

[78] Martina Pulcinelli, Mariangela Pinnelli, Carlo Massaroni, Daniela Lo Presti, Giancarlo Fortino, and Emiliano Schena. 2023. Wearable Systems for Unveiling Collective Intelligence in Clinical Settings. *Sensors* 23, 24 (January 2023), 9777. https://doi.org/10.3390/s23249777

[79] Andreas Pursche. 2014. Exploring collaboration requirements of heterogeneous teams on the example of a critical sales process. In *Proceedings of the International Conference on Information Systems and Design of Communication*, May 16, 2014. ACM, Lisbon Portugal, 93–98. https://doi.org/10.1145/2618168.2618183

[80] James Randall-James and Annabel Head. 2018. Taking conversations forward: a systemic exercise for teams threatened by service

restructures. *Journal of Family Therapy* 40, 3 (August 2018), 447–458. https://doi.org/10.1111/1467-6427.12184

[81] Réne Reiners, Michael Falkenthal, Dierk Jugel, and Alfred Zimmermann. 2013. Requirements for a collaborative formulation process of evolutionary patterns. In *Proceedings of the 18th European Conference on Pattern Languages of Program*, July 10, 2013. ACM, Irsee Germany, 1–12. https://doi.org/10.1145/2739011.2739027

[82] Nico Reski, Aris Alissandrakis, Jukka Tyrkkö, and Andreas Kerren. 2020. “Oh, that’s where you are!” – Towards a Hybrid Asymmetric Collaborative Immersive Analytics System. In *Proceedings of the 11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society* (*NordiCHI ’20*), October 26, 2020. Association for Computing Machinery, New York, NY, USA, 1–12. https://doi.org/10.1145/3419249.3420102

[83] Vincent Rousseau, Caroline Aubé, and André Savoie. 2006. Teamwork Behaviors: A Review and an Integration of Frameworks. *Small Group Research* 37, 5 (October 2006), 540–570. https://doi.org/10.1177/1046496406293125

[84] Esa Saarinen and Raimo Hämäläinen. 2004. *Systems Intelligence: Connecting Engineering Thinking with Human Sensitivity*. Helsinki University of Technology, Espoo, Finland.

[85] Esa Saarinen and Tuuli Lehti. 2014. Inducing Mindfulness Through Life-Philosophical Lecturing. . 1105–1131. https://doi.org/10.1002/9781118294895.ch57

[86] Richard Saavedra, P. Christopher Earley, and Linn Van Dyne. 1993. Complex interdependence in task-performing groups. *Journal of Applied Psychology* 78, 1 (1993), 61–72. https://doi.org/10.1037/0021-9010.78.1.61

[87] Eduardo Salas, Marissa L. Shuffler, Amanda L. Thayer, Wendy L. Bedwell, and Elizabeth H. Lazzara. 2015. Understanding and Improving Teamwork in Organizations: A Scientifically Based Practical Guide. *Human Resource Management* 54, 4 (2015), 599–622. https://doi.org/10.1002/hrm.21628

[88] Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2008. Co-creation and the new landscapes of design. *CoDesign* 4, 1 (March 2008), 5–18. https://doi.org/10.1080/15710880701875068

[89] Isabella Seeber. 2013. Facilitating Team Processes with Recommender Systems: A Behavioral Science Perspective. In *Proceedings of the 13th International Conference on Knowledge Management and Knowledge Technologies*, September 04, 2013. ACM, Graz Austria, 1–8. https://doi.org/10.1145/2494188.2494215

[90] Peter M. Senge. 1994. *The fifth discipline: the art and practice of the learning organization*. Doubleday/Currency, New York.

[91] Hannes Seppänen, Jaana Mäkelä, Pekka Luokkala, and Kirsi Virrantaus. 2013. Developing shared situational awareness for emergency management. *Safety Science* 55, (June 2013), 1–9. https://doi.org/10.1016/j.ssci.2012.12.009

[92] Sharp, Helen Sharp, Jennifer Preece, Jennifer Preece, and Helen Sharp. 2023. *Interaction Design: Beyond Human-Computer Interaction*. Wiley-Blackwell.

[93] Rurika Shimizu, Yutaka Takase, and Yukiko I Nakano. 2017. Audio based group conversation support system. In *Proceedings of the 2017 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2017 ACM International Symposium on Wearable Computers*, September 11, 2017. ACM, Maui Hawaii, 197–200. https://doi.org/10.1145/3123024.3123079

[94] Heikki Sjöman, Martin Steinert, Greg Kress, and Matteo Vignoli. 2015. Dynamically capturing engineering team interactions with wearable technology. *DS 80-11 Proceedings of the 20th International Conference on Engineering Design (ICED 15) Vol 11:Human Behaviour in Design, Design Education; Milan, Italy, 27-30.07.15* (2015), 153–162.

[95] Seokwoo Song, Seungho Kim, John Kim, Wonjeong Park, and Dongsun Yim. 2016. TalkLIME: mobile system intervention to improve parent-child interaction for children with language delay. In *Proceedings of the 2016 ACM International Joint Conference on Pervasive and Ubiquitous Computing*, September 12, 2016. ACM, Heidelberg Germany, 304–315. https://doi.org/10.1145/2971648.2971650

[96] Valdeon Sozo and André Ogliari. 2019. Stimulating design team creativity based on emotional values: A study on idea generation in the early stages of new product development processes. *International Journal of Industrial Ergonomics* 70, (March 2019), 38–50. https://doi.org/10.1016/j.ergon.2019.01.003

[97] Constantine Stephanidis, Gavriel Salvendy, Margherita Antona, Jessie Y. C. Chen, Jianming Dong, Vincent G. Duffy, Xiaowen Fang, Cali Fidopiastis, Gino Fragomeni, Limin Paul Fu, Yinni Guo, Don Harris, Andri Ioannou, Kyeong-ah (Kate) Jeong, Shin’ichi Konomi, Heidi Krömker, Masaaki Kurosu, James R. Lewis, Aaron Marcus, Gabriele Meiselwitz, Abbas Moallem, Hirohiko Mori, Fiona Fui-Hoon Nah, Stavroula Ntoa, Pei-Luen Patrick Rau, Dylan Schmorrow, Keng Siau, Norbert Streitz, Wentao Wang, Sakae Yamamoto, Panayiotis Zaphiris, and Jia Zhou. 2019. Seven HCI Grand Challenges. *International Journal of Human–Computer Interaction* 35, 14 (August 2019), 1229–1269. https://doi.org/10.1080/10447318.2019.1619259

[98] Tony Stockman and Nela Brown. 2013. Examining the use of thematic analysis as a tool for informing design of new family communication technologies. In *Proceedings of the 27th International BCS Human Computer Interaction Conference* (*BCS-HCI ’13*), September 09, 2013. BCS Learning & Development Ltd., Swindon, GBR, 1–6.

[99] Adam C. Stoverink, Bradley L. Kirkman, Sal Mistry, and Benson Rosen. 2020. Bouncing back together: Toward rhetorical model of work team resilience. *The Academy of Management Review* 45, 2 (2020), 395–422. https://doi.org/10.5465/amr.2017.0005

[100] Shree Krishna Subburaj, Angela E.B. Stewart, Arjun Ramesh Rao, and Sidney K. D’Mello. 2020. Multimodal, Multiparty Modeling of Collaborative Problem Solving Performance. In *Proceedings of the 2020 International Conference on Multimodal Interaction*, October 21, 2020. ACM, Virtual Event Netherlands, 423–432. https://doi.org/10.1145/3382507.3418877

[101] Geng Sun and Jun Shen. 2013. Teamwork as a Service: A Cloud-Based System for Enhancing Teamwork Performance in Mobile Learning. In *2013 IEEE 13th International Conference on Advanced Learning Technologies*, July 2013. IEEE, Beijing, China, 376–378. https://doi.org/10.1109/ICALT.2013.115

[102] Wanyi Tang. 2018. Understanding Esports from the Perspective of Team Dynamics. *The Sport Journal* 21 (July 2018), 1–14.

[103] Jenna Thelen, Carmen Sant Fruchtman, Muhammad Bilal, Kebabonye Gabaake, Shahid Iqbal, Tshiamo Keakabetse, Aku Kwamie, Ellen Mokalake, Lucia Mungapeyi Mupara, Onalenna Seitio-Kgokgwe, Shamsa Zafar, and Daniel Cobos Muñoz. 2023. Development of the Systems Thinking for Health Actions framework: a literature review and a case study. *BMJ Glob Health* 8, 3 (March 2023), e010191. https://doi.org/10.1136/bmjgh-2022-010191

[104] Teemu Tiinanen, Juha Törmänen, Raimo Hämäläinen, and Esa Saarinen. 2015. PoSITeams – Positive Systems Intelligent Teams, an Agent-Based Simulator for Studying Group Behaviour. January 01, 2015. .

[105] Juha Törmänen, Raimo P. Hämäläinen, and Esa Saarinen. 2016. Systems intelligence inventory. *TLO* 23, 4 (May 2016), 218–231. https://doi.org/10.1108/TLO-01-2016-0006

[106] Juha Törmänen, Raimo P. Hämäläinen, and Esa Saarinen. 2022. On the systems intelligence of a learning organization: Introducing a new measure. *Human Resource Development Quarterly* 33, 3 (2022), 249–272. https://doi.org/10.1002/hrdq.21455

[107] François Toutain and Emmanuel Le Huérou. 2015. A case-study in all-web rich interpersonal communication services. In *Proceedings of the 1st Workshop on All-Web Real-Time Systems*, April 21, 2015. ACM, Bordeaux France, 1–6. https://doi.org/10.1145/2749215.2749217

[108] Sinan Ugurlu and Detlef Gerhard. 2017. Supporting development teams in the early stages of product development through DfX-based knowledge management system and communication platform. *DS 87-6 Proceedings of the 21st International Conference on Engineering Design (ICED 17) Vol 6: Design Information and Knowledge, Vancouver, Canada, 21-25.08.2017* (2017), 121–130.

[109] Ralph Vacca. 2019. Brokering Data: Co-Designing Technology with Latina Teens to Support Communication with Parents: Leveraging Cultural Practices of Latinx Youth through Co-Design. In *Proceedings of the 18th ACM International Conference on Interaction Design and Children*, June 12, 2019. ACM, Boise ID USA, 197–207. https://doi.org/10.1145/3311927.3323142

[110] Josina Vink. 2023. Embodied, Everyday Systemic Design - A Pragmatist Perspective. *Design Issues* 39, 4 (October 2023), 35–48. https://doi.org/10.1162/desi_a_00731

[111] Hana Vrzakova, Mary Jean Amon, Angela E. B. Stewart, and Sidney K. D'Mello. 2019. Dynamics of Visual Attention in Multiparty Collaborative Problem Solving using Multidimensional Recurrence Quantification Analysis. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, May 02, 2019. ACM, Glasgow Scotland Uk, 1–14. https://doi.org/10.1145/3290605.3300572

[112] Ying Wang and Yan Liu. 2013. Comprehensive evaluation of enterprise's technological innovation talent team based on analytic network process and grey related analysis. In *2013 6th International Conference on Information Management, Innovation Management and Industrial Engineering*, November 2013. IEEE, Xi'an, China, 201–204. https://doi.org/10.1109/ICIII.2013.6702909

[113] Jacob O. Wobbrock and Julie A. Kientz. 2016. Research contributions in human-computer interaction. *interactions* 23, 3 (April 2016), 38–44. https://doi.org/10.1145/2907069

[114] Svetlana Yarosh, Anthony Tang, Sanika Mokashi, and Gregory D. Abowd. 2013. "almost touching": parent-child remote communication using the sharetable system. In *Proceedings of the 2013 conference on Computer supported cooperative work*, February 23, 2013. ACM, San Antonio Texas USA, 181–192. https://doi.org/10.1145/2441776.2441798

[115] Stephen J. Zaccaro, Samantha Dubrow, Elisa M. Torres, and Lauren N. P. Campbell. 2020. Multiteam Systems: An Integrated Review and Comparison of Different Forms. *Annual Review of Organizational Psychology and Organizational Behavior* 7, Volume 7, 2020 (January 2020), 479–503. https://doi.org/10.1146/annurev-orgpsych-012119-045418

[116] John Zimmerman, Erik Stolterman, and Jodi Forlizzi. 2010. An analysis and critique of Research through Design: towards a formalization of a research approach. In *Proceedings of the 8th ACM Conference on Designing Interactive Systems* (*DIS '10*), August 16, 2010. Association for Computing Machinery, New York, NY, USA, 310–319. https://doi.org/10.1145/1858171.1858228

[117] ISO 9241-210:2019. Retrieved August 20, 2024 from https://www.iso.org/standard/77520.html

A APPENDICES

A.1 Search queries

A.1.1 ACM

[[Title: team*] OR [Title: interaction] OR [Title: communication] OR [Title: interdependent] OR [Title: collabor*] OR [Title: group*] OR [Title: interpersonal] OR [Title: *feedback]] AND [[Title: service] OR [Title: product] OR [Title: technological solution] OR [Title: process] OR [Title: procedure] OR [Title: solution] OR [Title: proto*] OR [Title: system*]] AND [E-Publication Date: (01/01/2013 TO 12/31/2023)]

A.1.2 Scopus

(TITLE (team* OR interaction OR communication OR interdependent OR collabor* OR group* OR interpersonal OR *feedback) AND TITLE (service OR product OR technological AND solution OR process OR procedure OR solution OR proto* OR system*)) AND PUBYEAR > 2012 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "re"))