Image Schema vs VAKOG: Designing for Intuitive Communication in Air Traffic Control

Stephan Huber[1], Andreas Balser[1], Linda Pöhland[1], Patrick Schulz[1], Cordula Baur[1] and Jörn Hurtienne[1]

[1]*Julius-Maximilians-Universität Würzburg, Chair of Psychological Ergonomics, Oswald-Külpe-Weg 82, 97074 Würzburg, Germany*

Abstract

Real time audio communication makes up a major part of air traffic controllers' task in the feeder position because their aim is to optimize spacing between aircraft in the final approach. Since the audio channel is currently the communicative bottleneck and incoming audio requests may act as interruptions, written asynchronous communication pose a possible solution. In this work, we take inspiration from two cognitive theories that describe how people think about their environment and can be instantiated in language. We use those expressions to design communication interfaces that match the mental models of air traffic controllers and thus support an efficient workflow: Image Schematic Metaphors (ISM) rely on universal senso-motoric experiences and facilitate intuitive and hence efficient designs. In contrast, sensory preferences (VAKOG) emphasize individual differences between users and indicate a demand for either configurable or redundantly coded interfaces.

We describe both theories, provide an overview of our formative design process and contribute insights about the suitability and strengths of either theory for this safety critical domain. While flexible systems with redundant input and output modalities (VAKOG) benefit efficiency in various situations for all users, universally intuitive designs that emphasize the shared mental model (ISM) are more appropriate for the safety critical domain of air traffic control. In short, universality – a promise of image schema theory – beats inter-individual differentiation.

Keywords

air traffic control, image schema, VAKOG, design methods

1. Introduction

The air traffic controllers' task is to ensure the safe, orderly and expeditions handling of air traffic in their sector and comprises the communication with pilots, supervisors, and colleagues from neighboring sectors as well as the documentation of all clearances they give. In the approach sector, due to the dense traffic and low tolerance to conversational delays, currently all communication takes place verbally over radio frequency. Hence, the radio frequency is often the bottleneck of how much traffic a controller can handle [1]. Text messages between pilots and controllers for less urgent matters have been designed with a focus on the upper airspace [2] and would not only take load off the radio frequency but also allow for a direct documentation of clearances through text-based communication. As most conversations between approach control and pilots is time critical, we restrict our initial focus on the communication between controllers in the neighboring sectors of approach and tower control.

The priorities in air traffic control are the objectives safety, structure, and efficiency – in this order [e.g., 3]. Improvements towards efficiency therefore must not be at the expense of safety or structure. This means for instance, that the highly standardized communication in air traffic control needs to be

The Seventh Image Schema Day (ISD7), September 2, 2023, Rhodes, Greece
EMAIL: stephan.huber@uni-wuerzburg.de (S. Huber); andreas.balser@stud-mail.uni-wuerzburg.de (A. Balser); linda.poehland@stud-mail.uni-wuerzburg.de (L. Pöhland); patrick-schulz@freenet.de (P. Schulz); cordula.baur@uni-wuerzburg.de (C. Bauer); hurtienne@acm.org (J. Hurtienne)
ORCID: 0000-0002-5619-3222 (S. Huber); 0000-0002-4143-1531 (A. Balser); 0000-0002-0228-9747 (C. Bauer); 0000-0001-5295-9772 (J. Hurtienne);

maintained. Because this standardized communication consists of many short conversational turns, the cumulative interactional overhead of sending and receiving text messages would have a high impact on air traffic controllers' workload. We strive to minimize this impact by creating a communicational interface that is in accordance with air traffic controllers' mental models, hence, is more intuitive-to-use and, therefore causes a lower workload. To design for air traffic controllers' mental models and create intuitive-to-use interfaces, we followed two different approaches based on two cognitive theories which we compare in this work. In short, both, *image schematic metaphors* and *sensory preferences* describe how people think about their environment and as a result can be instantiated in language. Taking inspiration from those language instantiations during the design process contributes to more intuitive-to-use interfaces.

1.1. Image Schematic Metaphors

Image Schema theory is based on the inclusive idea of shared sensory motor experiences that we as humans make already when we explore our environment as infants. According to image schema theory, our bodily experiences manifest in abstractly represented recurring mental patterns of dynamic building blocks – so called image schemas [4, 5]. Because the physical laws constraining our environment do not vary around the globe, we all make similar bodily experiences that result in universally shared image schemas. We then metaphorically reapply those image schemas to make sense of new domains [6]. Such image schematic metaphors (ISM) occur in our language and represent our mental models. A common example is the metaphor MORE IS UP. From water levels or stacks of leaves we learn cross-culturally that larger quantities (MORE) of a thing can be associated with a higher pile (UP). Consequently, we apply this knowledge to non-tangible domains such as the "*high* volume of a sound", "*a mountain* of work ahead" or "*rising* stress levels", which can be instantiated in language. Hence, the users' language can be the key to understanding how people think [6, 7]. Applying ISM to interface design contributes to intuitive interactions, because we know already that pushing a sound-lever UP makes the music louder (MORE IS UP) or dragging the slider in a movie player allows us to navigate within the movie's timeline (TIME IS A PATH) [8].

Adhering to ISM during the design process has resulted in intuitive [6, 9] and age-inclusive [10] interfaces in various domains, including safety critical applications such as aviation and automotive interfaces [8, 11].

1.2. Sensory Preferences: VAKOG

The acronym VAKOG is made up of the initials of the five sensory channels **v**isual, **a**uditory, **k**inesthetic, **o**lfactory, and **g**ustatory. The VAKOG theory in short, describes that each individual has a preferred sensory channel which also dominates their mental model and language. Analyzing a persons' use of sensory vocabulary in their language allows us to infer their preferred channel(s) [12]. Using language or interfaces that match users' mental model of the world may benefit their interaction with the environment. Research on large language corpora indicated that the first three perceptual channels (visual, auditory, and kinesthetic) are most prevalent in users' language [e.g., 12]. For instance, persons talking about future events or plans may tell how they "feel good about it" (kinesthetic), "that sounds good" (auditory), or "we will see how that turns out" (visually) [13]. Publications from multiple disciplines and of varying scientific rigor (see [14] for a critical review) are sometimes labeled as neuro linguistic programming (NLP) and present the prospect of better interpersonal communication when adhering to a communication partner's preferred sensory vocabulary. This may increase rapport in general [15], create an environment of trust for interviewees to share their knowledge [13], benefit individual learners in classroom environments [16], or inform user models [17] which ultimately pave the way for improved marketing messages and sales pitches [18]. While the idea of VAKOG does sound convincing, there is – to our knowledge – so far merely anecdotal evidence of VAKOG induced improvements to communication and no interaction designs that were directly derived from a VAKOG analysis.

In sum, designing one interface for all that covers a collective understanding of the world gained from multi modal experiences (ISM) [19] versus optimizing interfaces for individuals based on their preferred sensory channel (VAKOG) are two opposing approaches which still implement the same goal of intuitive-to-use interfaces for each user. In this work we follow both interaction design approaches in parallel and draw comparisons on the methods' feasibility and suitability for the domain of air traffic control. Due to this being the first deployment of VAKOG in a design project in contrast to ISM which have been successfully contributed to projects including visual design [20], physical design [21] and interaction design [22, 23], we assume that the prototype resulting from the use of ISM might have an advantage in the concluding user tests.

2. Design

To convey the approaches taken in our design process we make a distinction between (1) the needs driven approach that led to the functional requirements of the communicative systems and (2) the two linguistically driven approaches that inspired the interaction design of our prototypes. For a visualization of our research process see **Figure 1**. While the two designers (authors AB, LP) conducted the wall walk together and agreed upon a vision, for interaction design they each picked only one of the linguistically inspired approaches (ISM, VAKOG) and intentionally did not read into the other.

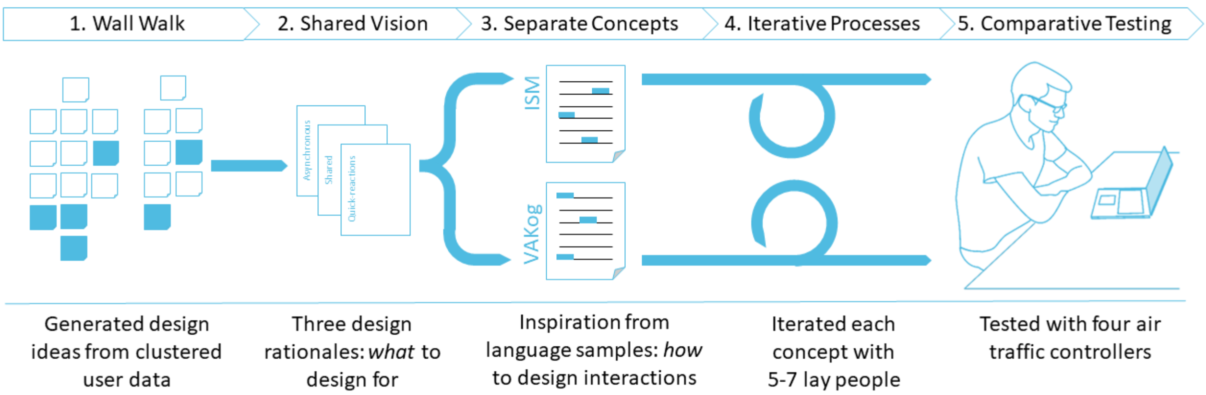

Figure 1: Depiction of our research process from user data over shared visions and forked concept iterations inspired by the two cognitive linguistics theories to user testing.

2.1. Deriving a Shared Set of Features

In our design process we deployed ideation methods suggested by Holtzblatt and Beyer [24] that led to a shared set of features. As those methods are not central to this works' line of argument, we will only briefly summarize them: a wall walk on clustered data in the form of affinity diagrams and experience models resulted in key insights and hot ideas (**Figure 1**.1). Those insights and ideas lay the basis for visions addressing opportunities for more efficient communication between air traffic controllers (**Figure 1**.2). Our final, consolidated vision incorporates the three following design rationales:

- **Asynchronous communication.** Controllers on both, the approach and tower position find the current means of communication via squawk box (speaker fed by a permanent transponder connection) often disturbing. To smoothly embed communication in their workflow, reduce interruptions and increase mental efficiency, we need to support asynchronous communication.
- **Shared documentation.** Controllers are obliged to document the clearances (e.g., permission to change speed, altitude or heading) they give to aircraft in a shared system so that existing clearances can be processed by the system and are accessible by subsequent controllers on the aircraft's route. In addition to that, controllers use the same system to write down notes which are job related and only visible to themselves. During a shift change, controllers verbally instruct their colleague, conveying also non-documented information. Inefficiencies may arise when the new

controller at the workstation encounters that some information has been omitted at handover. Therefore, a novel communication system needs to encourage the continuous documentation of all clearances and coordination results, therefore allowing controllers to distinguish between shared written clearances and private notes.

- **Quick-reactions.** User data from contextual inquiries revealed that gratefulness plays a large role in controllers' communication. For instance, tower controllers thanked their colleagues on the feeder position when feeders anticipated the need for runway space for starting aircraft and created a gap even before tower controllers asked for it. Additionally, colleagues frequently express small requests that exceed the standard. This refers mostly to pilot-feeder interaction but may affect tower controllers as well. When wishes are granted or fulfilled, and the supplicant thanked the controllers for their extra effort, controllers may thank each other for their collaboration. A novel communication system needs to maintain this practice of kindness without blocking other communication on the frequency.

Against the recommendations by Hurtienne, Klöckner, Diefenbach, Nass and Maier [23] we did not include the extracted ISM into the wall walk to minimize the influence on the designer who worked with VAKOG instances only. For the sake of ideas unbiased by the other team member's theoretic approach we also refrained from drawing concrete interface ideas in the visioning process but focused on visualizing the "users' new life".

2.2. Designing Interactions from Language

Based on the same transcribed texts from interviews with eight air traffic controllers we used priorly extracted ISM and manually identified VAKOG instantiations (**Figure 1**.3). In the current design process, we took inspiration only from instantiations of either theory that were applicable to communication between air traffic controllers and then designed prototypical interfaces for asynchronous communication with Axure RP 10 (http://www.axure.com). Following the shared design rationales, both prototypes facilitated asynchronous communication, simple quick-reactions, and saving shared information as documentation. Due to the valuable time and scarce availability of air traffic controllers we initially iterated the prototypes based on feedback from the domain experience (gained during a 3-year project) of author SH, seven users who tested an early version of the ISM prototype and five users who tested an early version of the VAKOG prototype (**Figure 1**.4).

2.2.1. Designing with Image Schematic Metaphors

To conceptualize the communication interface author AB sourced appropriate ISM from publicly available lists of air traffic control specific [25] and generic [8, 22] ISM. Following the metaphor FEEDER IS A SURFACE, both working positions are represented as large areas (**Figure 2**). The current user's own working position is displayed closer to the bottom that is more body-centric than the conversation partner's working position (SIMILAR IS NEAR). By holding the microphone button, messages can be spoken into a text-to-speech system. The automatically transcribed messages appear next to the microphone icon and are then draggable towards the receiver's working position (FEEDER IS THE END OF A PATH). On the receiving side, incoming messages are accompanied by an acoustic signal. In contrast to current radio communication, messages are constantly available as text and not automatically read aloud to minimize the interruption. However, controllers can play the original audio file of the message if they seek to retrieve more tacit information [1]. Responses can be dictated as well or can be given as short quick-responses that can be sent via the reaction-buttons. Multiple sent messages superimpose each other (FUTURE IS FRONT). Important information can be dragged by either party onto a third area with shared content that is connected by lines to both users (CONVERSATION IS LINKAGE). Using Google's Material Design, the prototype is optimized for direct touch and could also be operated with a mouse.

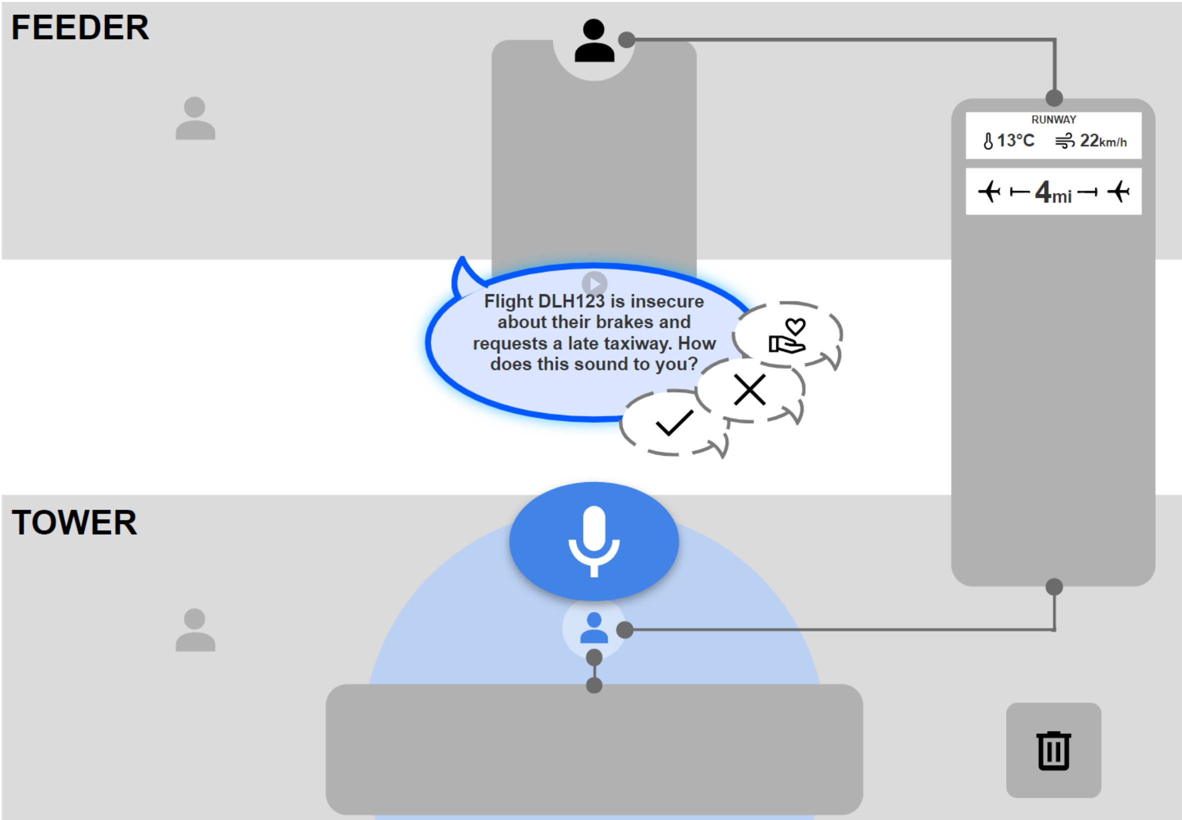

Figure 2: Click-prototype based on Image Schematic Metaphors. While the interface did not differ between the positions this screenshot depicts the Tower Controller's view on the communication. In this moment the Feeder sent a request to which the tower can either respond by using the quick reaction bubbles or sending a longer response via written or spoken text. Both controllers can choose to drag the text into the container with shared information on the righthand side if they consider the more prominent visibility of this information beneficial.

2.2.2. Designing with VAK Instantiations

Based on publicly available word lists for German VAKOG root words [26-36] author PS generated a lexicon of sensory vocabulary and systematically retrieved VAKOG instantiations from transcribed interviews with air traffic controllers. Since olfactory and gustatory preferences have been shown to be generally less prevalent [12] and are also not simple to design for in an environment with frequent conversational turns that requires efficiency we restricted the search to the VAK channels. The emerging tables of VAK vocabulary occurrences categorized by context was supposed to serve as inspiration for conceptualizing interactions with a communication interface. In many instances, the utterances are coined by the current interface. For instance, controllers talked about what they see on the "radar **picture**" or the audible qualities (**"definite", "dull"**) of radio conversation. However, there were also misalignments where the VAK wording did not match the sensory channel of the physical interface. An example for a visual and motoric instantiation of acting in a complex situation is "if this aircraft makes a go around, this changes **the picture** entirely for the tower controller and they have to **step in**". This is a mismatch with the primary perception of the aircrafts' go around and the action of the tower controller which both are communicated vocally via radio. Similarly, when air traffic controllers want to make sure their communication partner understands the urgency of a message, they lend their "voice a tone of insistence, **forcefulness** [translated from *Nachdrücklichkeit, Eindringlichkeit*]", which are kinesthetic descriptors for audible qualities.

Due to the lack of consistent VAKOG references to any context relevant to communication between controllers, author LP decided to leave the choice of channel to the individual. When initially setting up their interface, controllers were invited to select their preferred output channel. So incoming messages would be predominantly announced by either a visual or auditory signal or a short vibration of the input device. Additionally, the second sentence of the message visible in **Figure 3** was available in three versions. While the first, informative part remained fixed as “Flight DLH123 is insecure about their brakes and requests a late taxiway.”, depending on user’s initially set preference the system would automatically change the wording of the incoming message to either of three versions:

- **Visually:** How does that look from your perspective?
- **Auditory:** How does that sound for you?
- **Kinesthetic:** How does that suit for you?

In addition to that, messages can be entered into the system via voice, typing or handwriting. In this prototype messages could be marked as *important* through a star icon via context menu. While over multiple conversational turns the main chat may grow and older messages disappear from the screen, messages marked as *important* by either user are permanently displayed in the shared panel on the left.

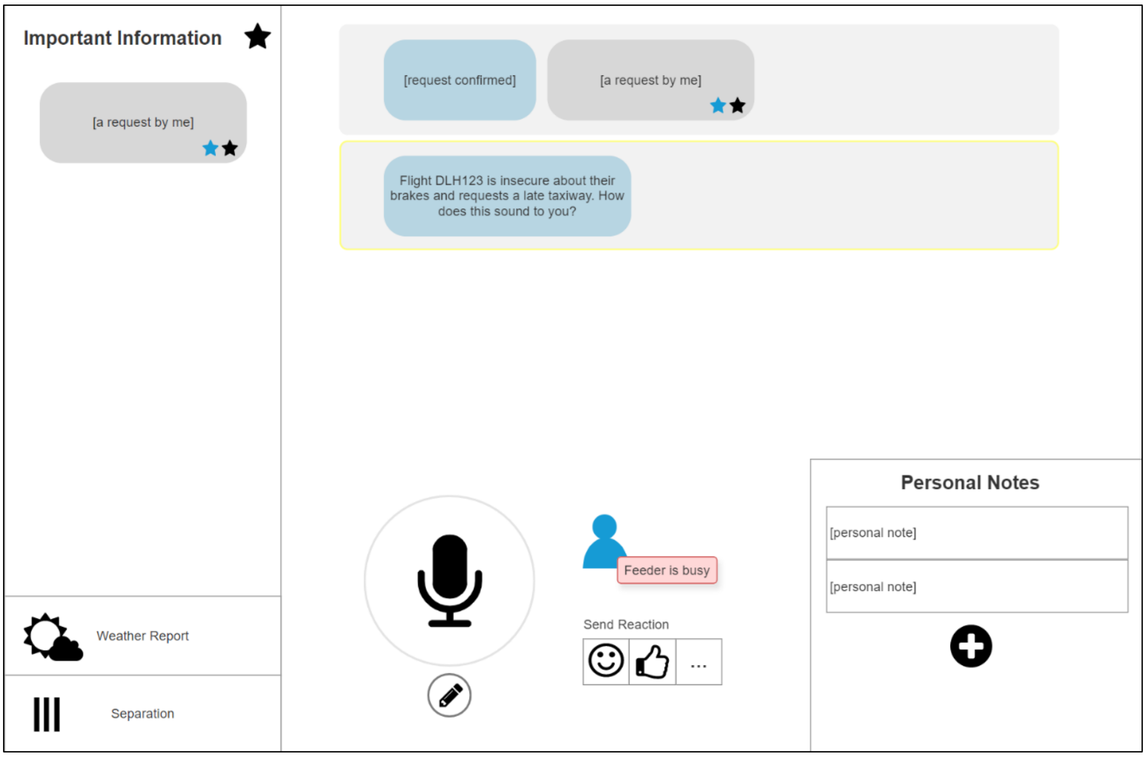

Figure 3: Click-prototype based on VAKog considerations. While the interface did not differ between the positions this screenshot depicts the Tower Controller’s view on the communication. Here, depending on the preferred channel, a sound, vibration, or yellow highlight notified the controller about the incoming request. In accordance with the functionality of the ISM prototype, the controller could respond either via sending a quick reaction symbol or typing or recording a longer response. By using a context menu (not visible in the screenshot; invocable from any message through long press on a touchscreen or right click with a mouse) controllers on both positions could highlight the importance of a message which resulted in the message being copied to the shared board on the left.

3. Comparative Testing

Finally, we conducted a short user test (**Figure 1**.5) to exploratively test which interface contributes to intuitive use and whether there are interaction concepts that support controllers despite their individual differences in working strategies. We presented the high-fidelity prototypes to four air traffic controllers who volunteered to participate in a remote study that lasted for about one hour. Participants used each prototype for 20 minutes. Since we did not measure objective efficiency we asked controllers to think aloud while completing the three following tasks that covered the prototypes’ main functionality [37]:

- Discussing a special request with a colleague in an adjacent sector.
- Confirming a request from the colleague and saving it as visible to both positions.
- Creating a note that is only visible to oneself.

Afterwards we interviewed controllers about their experience and differences between the prototypes for another 20 minutes. For the qualitative interview questions we took inspiration from the subscales of the Questionnaire for Intuitive Use (QUESI, [38]), asking if controllers found the interaction with the system complicated, if they reached their goals, and if they could imagine using the system during their work. During the interviews we paid particular attention to instantiations of ISM in controllers' language during use and contrasted them with the metaphors embedded in the interface [39]. From the notes taken during the study we inductively clustered observations and user statements.

4. Results

In this section we focus on results that are associated to either of the two theories and in the interest of brevity omit general insights on how to improve the interfaces.

4.1. Intuitive Use of the Interfaces

Building upon participants' prior knowledge of speech bubbles or icons commonly used in messengers increased their intuitive understanding of the prototypes already. Controllers had no trouble understanding the interaction concept of the more conventional VAKOG prototype with tapping interactions and context menus. However, there was a downside of prior experience with other touch-based messenger services which rely on tapping interactions for the ISM prototype: the drag & drop interaction to send recorded messages towards the receiver was not intuitive for controllers. When attempting to send messages, controllers interacted with the tower position (END OF A PATH), but it was not clear to them they needed to follow a full path with drag & drop and that this path started at the recording icon. Once explained, all participants considered the subsequent interactions clear, "self-explanatory", and natural. Their thinking aloud utterances when explaining the interface contained the embedded Image Schema, such as the LINKAGE between both positions to the shared information space.

Controllers considered the quick response with symbols and emoji a cool, fast, and non-verbal alternative. While they all intuitively understood the meaning of symbols and emoji intended by the designers, they were afraid that the intention behind the symbols could be ambiguous for colleagues and wished for a pre-shared central agreement on their meaning.

4.2. Multimodality

Across both prototypes our participants appreciated the multimodality in asynchronous messages. Controllers claimed that they would primarily read the messages and if they had the time, or were busy closely surveilling the radar interface, rather listened to the messages.

4.3. Trust in Language Automation

Instead of directly sending the message once dictated, participants found it important to check the written results of the speech-to-text system before sending a message. This appropriate mistrust in the reliability of speech recognition enforces a multimodal interaction during text input. Participants noted that the additional effort to visually check the text message causes an unintended delay, rendering this way of communication only suitable for not time critical instructions.

Similarly, controllers did not appreciate the automated alteration of their messages. Even after we explained them that the VAKOG optimization is intended to smoothen the communicative flow of non-standardized conversational turns, controllers remained skeptical. They feared, automatic changes to language could result in a misconception of the message's intention and urgency in their communication partner.

5. Discussion

In this work we strived towards more efficient communication between approach- and tower control through asynchronous communication. Lending from image schema theory and VAKOG should reduce mental workload and hence, cater for efficiency. We tested which of the cognitive theories is most appropriate to inspire designs in this context and expected an advantage of the field tested ISM.

With respect to the process, we found that ISM are suitable for designing in the domain of air traffic control. The main reason for the initial struggle with the ISM interaction concept during the user tests was that participants did not perceive the messages as draggable. This can be partly due to their expectations based on prior experience with other messengers. Another contributing factor may be that the flat design language did not sufficiently convey the affordance of the message as being draggable or the distinction of various "areas" as SURFACES where messages can lie upon. After an initial explanation controllers interacted flawlessly with the interface in all subsequent tasks and experienced no further interference with interaction concepts familiar from other messengers. All controllers considered both interfaces as intuitive to use.

With respect to the VAKOG differentiated interface, controllers appreciated the intended multimodality of messages in written text and spoken audio. There was no divide regarding preference for either channel between the controllers but rather a collective appreciation of the redundancy that may prove useful in varying situations. Seen through the lens of VAKOG [13], this stands in contrast to the initially analyzed language of controllers pointing towards individually different preferred channels. Hence, to cater for individual differences of air traffic controllers with respect to their preferred sensory channels we recommend to collectively cater for richer interaction modalities instead of manipulating the transmitted content. For instance, controllers' efficiency may benefit from a system that redundantly offers feedback on multiple sensory channels and possibly even allows multi-modal input. However, we advise to refrain from actively altering snippets of standardized communications between controllers, as this may change controllers' understanding in what their colleagues wanted to express. In sum, the aspects controllers favored in either interface that are attributable to a shared mental model and their preferences for sensory channels varied more between hypothetical situations than between individuals. An implication for designers for interfaces in air traffic control would be to rely on methods that support shared mental models, such as ISM and provide multimodal interactions redundantly without differentiating between individuals.

5.1. Limitations and Future Work

The early success tests [40] are promising, however, were run only in an oversimplified environment. Further iterations are necessary also with respect to the interfaces' applicability in simulated peak traffic. A further limitation of generalizability is that the interface concepts were optimized for the communication between approach and tower control of large airports. Controllers at smaller airports may handle less traffic but often cover multiple roles and communicate with more different actors at the same time which could lead to a more crowded interface.

Using symbols and emoji to abbreviate conversational turns in written communication is promising and was accepted by controllers, however, the meaning of symbols and emoji is often ambiguous. Before implementing symbols and emoji into air traffic control communication, their meaning needs to be standardized for this context or explicitly stated with subtitles.

Manually annotating linguistic evidence for sensory channels in the transcribed interviews was a lot of effort. It is alleviating to know that neither the manual search nor automatic and error prone lexical list matching [12] nor context-insensitive classification of perceptual preferences with questionnaires [41] are necessary. As people do not need to be classified by preferred sensory channel, the initial broad language analysis can be skipped. Instead, co-design sessions can provide a platform to let users choose the modality and interactions which matches their current resources [42, 43].

Not all design decisions in the prototypes can be justified with the ISM or VAKOG theories. Additionally, it became apparent during the user tests that the two theoretical lenses of ISM and VAKOG are not mutually exclusive. While it is hard to design without using ISM at least unintentionally [22] the same applies to VAKOG. In a safety critical domain such as air traffic control, addressing multiple sensory channels is a welcome advantage. However, designing for a shared mental model – as is supported by ISM – is indispensable.

6. Conclusion

In this work we contributed a first comparison of ISM and VAKOG for design processes. While the redundancy of sensory modalities inspired by VAKOG may improve individual efficiency in certain situations, the ISM had the advantage of ensuring a shared mental model of the communication. Aspects that supported the universality of the prototypes across users and situations, such as ISM and redundant channels were appreciated by users across prototypes. In short, universality – a promise of image schema theory – beats inter-individual differentiation. On the domain application level, insights from our design process and the resulting prototypical interfaces may offer inspiration for future generations of ATC communication terminals. In Future projects designers could combine the two approaches sequentially rather than contrast them. For instance, after having identified sentences that contain design relevant ISM, the linguistic context of those metaphors could be additionally examined for sensory vocabulary to inspire interaction design for all senses.

7. Acknowledgements

We are grateful for all air traffic controllers who shared their knowledge, strategies, and perspectives. We thank all partners and colleagues who helped to facilitate the studies.

8. References

[1] S. Huber, J. Gramlich, T. Grundgeiger. From Paper Flight Strips to Digital Strip Systems: Changes and similarities in air traffic control work practices, Proceedings of ACM Human-Computer Interaction 4, CSCW1 (2020), Article 028. URL: http://dx.doi.org/10.1145/3392833. doi: 10.1145/3392833.
[2] R. Bone, K. Long. Air Traffic Controller Utilization of Voice and Data Link Communications During Interval Management IEEE,°(2016) 2D1-1-2D1-16. URL: http://dx.doi.org/10.1109/ICNSURV.2016.7486335. doi: 10.1109/ICNSURV.2016.7486335.
[3] V. D. Hopkin. Man-Machine Interface Problems in Designing Air Traffic Control Systems, Proceedings of the IEEE 77, 11 (1989), 1634-1642. URL: http://dx.doi.org/10.1109/5.47726. doi: 10.1109/5.47726.
[4] M. M. Hedblom. Image schemas and concept invention: cognitive, logical, and linguistic investigations. Thesis, Dissertation, Magdeburg, Otto-von-Guericke-Universität Magdeburg, 2018, (2018).
[5] J. M. Mandler. The foundations of mind: Origins of conceptual thought. Oxford University Press, (2004).
[6] J. Hurtienne, J. H. Israel. Image schemas and their metaphorical extensions: intuitive patterns for tangible interaction, in Proceedings of the 1st international conference on Tangible and embedded interaction, 2007, 127-134. URL: http://dx.doi.org/10.1145/1226969.1226996. doi: 10.1145/1226969.1226996.
[7] M. Johnson. The body in the mind: The bodily basis of meaning, imagination, and reason. University of Chicago press, (1987).
[8] J. Hurtienne, D. Löffler, C. Hüsch, D. Reinhardt, R. Tscharn, S. Huber. Happy is Up, Sad is Down - 65 Metaphors for Design. BIS Publishers, (2020).
[9] D. Löffler, A. Hess, A. Maier, J. Hurtienne, H. Schmitt. Developing intuitive user interfaces by integrating users' mental models into requirements engineering, in Proceedings of the 27th International BCS Human Computer Interaction Conference (HCI 2013) 27, 2013, 1-10. URL: http://dx.doi.org/10.14236/ewic/HCI2013.14. doi: 10.14236/ewic/HCI2013.14.

[10] R. Tscharn. Design of Age-Inclusive Tangible User Interfaces Using Image-Schematic Metaphors ACM, Yokohama, Japan,°(2017) 693-696. URL: http://dx.doi.org/10.1145/3024969.3025036. doi: 10.1145/3024969.3025036.
[11] A. Winkler, K. Baumann, S. Huber, R. Tscharn, J. Hurtienne. Evaluation of an Application Based on Conceptual Metaphors for Social Interaction Between Vehicles, in Proceedings of the 2016 ACM Conference on Designing Interactive Systems, Association for Computing Machinery, 2016, 1148–1159. URL: http://dx.doi.org/10.1145/2901790.2901876. doi: 10.1145/2901790.2901876.
[12] G. Kellner, B. Berendt. Extracting knowledge about cognitive style, in Proceedings of the 2011 7th International Conference on Natural Language Processing and Knowledge Engineering, 73-79. URL: http://dx.doi.org/10.1109/NLPKE.2011.6138172. doi: 10.1109/NLPKE.2011.6138172.
[13] P. F. Micciche, J. S. Lancaster. Application of Neurolinguistic Techniques to Knowledge Acquisition, SIGART Bull., 108 (1989), 28–33. URL: http://dx.doi.org/10.1145/63266.63270. doi: 10.1145/63266.63270.
[14] M. S. Remland. Madonik, B. I hear what you say, but what are you telling me? The strategic use of nonverbal communication in mediation. San Francisco: Jossey-Bass, 2001, Conflict Resolution Quarterly 20, 1 (2002), 121-127. URL: http://dx.doi.org/10.1002/crq.14. doi: 10.1002/crq.14.
[15] M. Mishra, S. P. Satpathy, R. M. Dash, A. Mishra. A Study on the NLP Dimensions of Rapport Building and Its Effect on Interpersonal Communication, Specialusis Ugdymas 1, 43 (2022), 1058-1066.
[16] J. Prabowo. Optimizing VAKOG as human senses in teaching English for young learners, Language Circle: Journal of Language and Literature 10, 1 (2015). https://journal.unnes.ac.id/nju/index.php/LC/article/view/4157.
[17] G. Kellner, B. Berendt. Towards a New Dimension for User Modeling: The Use of Sensory Vocabulary, in Proceedings of the Advances in User Modeling, Springer Berlin Heidelberg, 397-401.
[18] R. Flachenäcker. Menschentypen – Menschen einschätzen [Human types – assessing humans]. R. Flachenäcker. Springer Fachmedien Wiesbaden, Wiesbaden,°(2019) 105-126. URL: http://dx.doi.org/10.1007/978-3-658-25909-9_13. doi: 10.1007/978-3-658-25909-9_13.
[19] B. Hampe. Image schemas in cognitive linguistics: Introduction,°(2005) 1-12.
[20] J. M. Cunha, P. Martins, P. Machado. Using Image Schemas in the Visual Representation of Concepts, in Proceedings of the The Fourth Image Schema Day (ISD4), CEUR Workshop Proceedings, 2019, 1-11. http://ceur-ws.org/Vol-3140/paper2.pdf.
[21] C. Baur, C. Wienrich, J. Hurtienne. Designing Data Physicalisations – with Physical Image Schema Instantiations, in Proceedings of the ETIS 2022, CEUR Workshop Proceedings, 2022, 1-7. http://ceur-ws.org/Vol-3328/workshop4.pdf.
[22] R. Tscharn. Innovative And Age-Inclusive Interaction Design with Image-Schematic Metaphors. Ph.D. Thesis, (2019). URL: http://dx.doi.org/10.25972/OPUS-17576. doi: 10.25972/OPUS-17576.
[23] J. Hurtienne, K. Klöckner, S. Diefenbach, C. Nass, A. Maier. Designing with image schemas: resolving the tension between innovation, inclusion and intuitive use, Interacting with Computers 27, 3 (2015), 235-255. URL: http://dx.doi.org/10.1093/iwc/iwu049. doi: 10.1093/iwc/iwu049.
[24] K. Holtzblatt, H. Beyer. Contextual Design: Design for Life. Morgan Kaufmann, (2017).
[25] S. Huber, P. Schulz, E. Hauke, J. Hurtienne. Image schematic metaphors in air traffic controllers' language, in Proceedings of the The Sixth Image Schema Day (ISD6), CEUR Workshop Proceedings, 2022, 1-9. http://ceur-ws.org/Vol-3140/paper2.pdf.
[26] N.-Z. Berlin. VAKOG, retrieved July 1st 2022. URL: https://nlp-zentrum-berlin.de/infothek/nlp-glossar/vakog.
[27] D. G. Frings. 3 einfache Tricks – und Ihr Text kommt 100%ig beim Leser an! [Three simple tricks to convey your text to a 100% to the reader!], 2018. URL: https://schreibenundleben.com/3-einfache-tricks-und-ihr-text-kommt-beim-leser-an/.
[28] T. Deutsch. Erkennen der im NLP bekannten Metaprogramme bei der/dem Mitarbeiterrekrutierung/Mitarbeitergespräch, um den Mitarbeiter entsprechend seiner Fähigkeiten einzusetzen [Recognizing Metaprograms known to NLP during recruting and staff appraisal to deploy the employee according to their skills]. Diploma Thesis, (2011). https://monami.hs-mittweida.de/files/2088/Diplomarbeit_ABGABE_UD.pdf.

[29] HSB-Akademie. Wahrnehmungskanäle [sensory channels], retrieved on July 1st 2022. URL: https://hsb-akademie.de/wahrnehmungskanaele/.
[30] Landsiedel-Seminare. NLP-Modell: VAKOG, retrieved July 1st 2022. URL: https://www.landsiedel-seminare.de/nlp-bibliothek/practitioner/p-02-00-repraesentationssysteme.html.
[31] NLPedia. VAKOG(2021). https://www.nlpportal.org/nlpedia/wiki/VAKOG.
[32] Profiling.me. Die fünf menschlichen Sinne VAKOG [the five human senses](2019). https://www.profiling.me/vakog.
[33] P. Schmid. Richtig kommunizieren – wie du von allen verstanden wirst [communicating correctly – how you get understood by everyone](retrieved July 1st 2022). https://www.schmid-philipp.com/richtig-kommunizieren/.
[34] Texterclub. Texten für alle Sinne [Texting for all senses](retrieved July 1st 2022). https://www.texterclub.de/texten-fuer-alle-sinne/.
[35] ThinkNeuro. Tipp der Woche: Visuelle und Auditive Wörter [Weekly tip: visual and auditive words](2014). https://www.thinkneuro.de/2014/04/07/tipp-der-woche-visuelle-und-auditive-woerter/.
[36] buchstaben.com. Synonyme für: visuell [synonyms for 'visual'](retrieved July 1st 2022). https://www.buchstaben.com/synonym/visuell.
[37] M. Hertzum, K. D. Hansen, H. H. K. Andersen. Scrutinising usability evaluation: does thinking aloud affect behaviour and mental workload?, Behaviour & Information Technology 28, 2 (2009), 165-181. URL: http://dx.doi.org/10.1080/01449290701773842. doi: 10.1080/01449290701773842.
[38] A. Naumann, J. Hurtienne. Benchmarks for intuitive interaction with mobile devices, in Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, ACM, Lisbon, Portugal, 2010, 401-402. URL: http://dx.doi.org/10.1145/1851600.1851685 doi: 10.1145/1851600.1851685
[39] O. K. Asikhia. Evaluating intuitive interactions using image schemas. Ph.D. Thesis, Cardiff University, (2015). https://orca.cardiff.ac.uk/id/eprint/89364/.
[40] B. Rabiller, N. Fota, L. Carbo. SESAR Safety Reference Material (D4.0.060). Eurocontrol. Brussels, Belgium,°(2018) 51 pages. https://www.sesarju.eu/sites/default/files/documents/transversal/SESAR2020%20Safety%20Reference%20Material%20Ed%2000_04_01_1%20(1_0).pdf.
[41] G. Kellner, M. Berthold. I-Know My Users: User-Centric Profiling Based on the Perceptual Preference Questionnaire (PPQ), i-KNOW '12(2012). URL: http://dx.doi.org/10.1145/2362456.2362493. doi: 10.1145/2362456.2362493.
[42] F. Bircanin, M. Brereton, L. Sitbon, B. Ploderer, A. Azaabanye Bayor, S. Koplick. Including Adults with Severe Intellectual Disabilities in Co-Design through Active Support, Chi '21(2021). URL: http://dx.doi.org/10.1145/3411764.3445057. doi: 10.1145/3411764.3445057.
[43] K. Neidlinger, S. Koenderink, K. P. Truong. Give the Body a Voice: Co-Design with Profound Intellectual and Multiple Disabilities to Create Multisensory Wearables, Chi Ea '21(2021). URL: http://dx.doi.org/10.1145/3411763.3451797. doi: 10.1145/3411763.3451797.