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RESEARCH ARTICLE



Designing augmentative and alternative communication systems with Aboriginal Australians: vocabulary representation, layout, and access

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ABSTRACT

Yolŋu (Aboriginal Australians of northeast Arnhem Land) are interested in developing augmentative and alternative communication (AAC) systems in their own languages to support communication opportunities and participation for their family members living with Machado–Joseph disease. Designing AAC systems in Aboriginal languages requires consideration of unique linguistic and cultural elements. Participatory action research in strength-based communication contexts was carried out by Yolŋu and *Balanda* (the Yolŋu word for non-Aboriginal people) researchers working together through a collaborative intercultural process. Culturally responsive literacy, language, and AAC activities were used to develop four prototype Yolŋu AAC systems for Yolŋu with varied literacy skills. Data were coded using gerunds to identify and focus on action in the data. Reflective and analytical collaborative, oral group discussions were used to identify key considerations and, ultimately, a Yolŋu metaphor for the research. Yolŋu language, culture and worldview impacted all aspects of prototype design and decision making. Salient considerations related to representation, organization, layout, and access, are presented. Clinical implications and future research considerations are outlined.

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Machado–Joseph disease (MJD) is a rare, autosomal dominant neurodegenerative disease with very high prevalence in remote Australian Aboriginal communities (Carr et al., 2019). Furthermore, prevalence in this region is likely to increase due to population isolation, consanguinity, and polygyny (LaGrappe et al., 2017). The disease causes progressive damage to cells in the cerebellum, resulting in gait and limb ataxia, dysarthria, dysphagia, visual disturbances (including nystagmus, diplopia and vestibulo-ocular, smooth pursuit, and saccadic abnormalities) and other symptoms but cognition is not affected (Rüb et al., 2004; Saute & Jardim, 2015). Allied health professionals play a crucial role in supporting people with MJD, including consideration of augmentative and alternative communication (AAC) interventions, community participation, fatigue management, and alternative access requirements (de Silva, 2019).

Yolŋu (Aboriginal Australians of Northeast Arnhem Land) with MJD are interested in working with speech-language pathologists (SLPs) to explore how AAC systems in their own languages could be developed collaboratively through a culturally responsive process (Amery et al., 2020). Northeast Arnhem Land is one of the most linguistically diverse regions

in the world. Approximately 12,000 Yolŋu speak at least one of more than 40 Yolŋu clan languages as their primary language (Christie & Charles Darwin University, 2016). Most Yolŋu understand and speak more than four clan languages, as well as varying degrees of English. Some Yolŋu are multilingual and bimodal, using Yolŋu Sign Language in everyday interactions (Maypilama & Adone, 2013). Varied family circumstances, experiences, education, and work opportunities mean that many Yolŋu do not feel confident reading or writing in their own first Yolŋu languages or English (Shalley & Stewart, 2017). Critically, motor impairments associated with severe MJD mean that unaided forms of AAC alone are unlikely to meet the complex communication needs of Yolŋu living with MJD.

Yolŋu ontology and epistemology is relational, performative, multi-perspective and narrative-based (Christie, 2001). In Yolŋu knowledge sharing, stories are used to emphasize, negotiate and encourage many connections, perspectives, possibilities and expressions of meaning (Christie, 2001; van Gelderen & Guthadjaka, 2017). Among Aboriginal people in Australia, there exists a variety of views about health and disability, including as imposed, colonial concepts from mainstream non-Indigenous healthcare provision and research

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(Gilroy & Donnelly, 2016). Wellbeing and sickness are interconnected with human behavior, social order, cultural practice, ceremony, spiritual wellbeing, and sorcery (Stopher & D'Antoine, 2008). Consideration of these priorities is important for the uptake of assistive technologies. Globally, evidence shows that when assistive technologies are developed collaboratively with Indigenous people to address their own concerns, incorporate Indigenous languages, and enable creative, culturally responsive, diversified use (for different purposes, by multiple family members), then technologies are more readily adopted (Jones et al., 2017).

English language, Western cultural contexts, and biomedical worldviews are still predominant in AAC research (Kulkarni & Parmar, 2017); worldwide, however, AAC in non-Western languages is a growing area of research and practice (Tönsing et al., 2018). Practitioners developing AAC in languages other than English must consider factors such as sound system, grammar, vocabulary organization, icons, writing, and cultural outlook (Baker & Chang, 2006). The syntactic structure of languages impacts the words and grammar selected for a system and the layout of vocabulary (Andres, 2006; Mngomezulu et al., 2019). An individual's languages and life experiences also impact their perception of graphic symbols (Karal et al., 2016). Multilingual systems need to allow for natural code-switching between languages (Tönsing et al., 2018). Furthermore, AAC practitioners working across languages and cultures must collaborate with families, linguists, and cultural advisors to develop appropriate AAC systems (Hetzroni & Harris, 1996). It is during the strategic and technological decision-making aspects of system design that people who use AAC are most vulnerable to the imposition of other cultural ways of communicating, particularly those of an SLP (Hetzroni & Harris, 1996).

Researchers working with other Indigenous populations in AAC, including Native American and Māori families, have identified the importance of being flexible and building trusting relationships over time. AAC must be developed by and with Indigenous peoples within the extended family context to enable authentic communication rather than "just someone who's pulled out a dictionary and put some Māori words on it" (Stone, 2019, p. 91). Incorporating Indigenous peoples' interconnected, holistic views, prioritizing of relationships, and communicating through storytelling, is also important (Stone, 2019; Stuart & Parette, 2002).

Yolŋu living with MJD in Australia have also expressed the importance of working collaboratively with extended family members, frequently in outdoor locations where they feel comfortable (Amery et al., 2020). In decolonizing disability research with Indigenous Australians, biomedical and impairment-based approaches and the way that these represent and frame Indigenous peoples must be challenged (Gilroy & Donnelly, 2016). Culturally responsive assessment with Yolŋu reflects use of strengths-based frameworks that value local cultural knowledges, practices, and perspectives, rather than deficit frameworks (Lowell et al., 2018). Metaphors are commonly used in collaborative work between Yolŋu and Balanda to acknowledge the different cultural constructs that inform lived experiences (Marika-

Mununggiritj & Christie, 1995). Yolŋu AAC systems and implementation must emphasize identity and relationships; adopt flexible methodology; allow for the sharing of narratives; and incorporate the expression of many cultural connections and knowledge to enable natural expression of Yolŋu language, identity, and culture.

This study used collaborative intercultural methods for conducting research with Yolŋu to develop prototype AAC systems. Researchers considered typical aspects of AAC system design, such as vocabulary representation, layout, and access, through a Yolŋu lens, in order to be responsive to Yolŋu processes and considerations. Because this process has never been applied to AAC system development, the researchers considered this study to be exploratory. The aims were to (a) collaboratively develop prototype AAC systems for Yolŋu adults living with MJD, and (b) document and share the emergent intercultural process of AAC system design in a culturally responsive way.

Method

This study (Study 3) is part of a broader communication research project with Yolŋu living with MJD and their families. In Study 1 (Amery et al., 2020), constructivist grounded theory was used to conduct a needs assessment to explore the views of Yolŋu living with MJD about communication, speech-language pathology services, and AAC. Study 2 (Amery et al., *in press*) used participatory action research (PAR) to explore the concept and development of an initial Yolŋu core vocabulary. Core vocabulary are words that occur frequently or are commonly used by many individuals (Laubscher & Light, 2020). The current paper (Study 3), a subsequent AAC system design study, reports on the development of Yolŋu AAC system prototypes designed to incorporate core vocabulary developed in Study 2 (Amery et al., *in press*). The same participants and researchers took part across all three studies and the same recruitment process, research design, and PAR methodology were used in all three studies.

Throughout this broader program of research, the principles of the metaphor *Goydhu* ("building understanding by hand") identified in Study 1 were applied. The metaphor *Gulaka-buma* ("harvesting yams"), identified toward the end of the data analysis phase in Study 2 (Amery et al., *in press*), is an applied example of *Goydhu* that was also used in the current study to represent and share the research process and findings in a culturally responsive way that centers Yolŋu voices and worldview. Using metaphors in collaborative research builds up layers and multiple perspectives so that new knowledge is connected to existing knowledge, and individuals can negotiate understandings (van Gelderen & Guthadjaka, 2019).

Participants

A total of 15 participants provided written and oral consent to participate in the study: 10 Yolŋu adults with a diagnosis of MJD (P1, P2, etc.) and 5 close adult family members (FM1, FM2, etc.). The participants were 4 males and 11 females, aged 18–56 years. The 10 Yolŋu adults presented with mild

Table 1. Participant characteristics.

Individual (P) and family members (FM)	Sex	Age range (years)	Stage of Machado–Joseph disease	No. of research sessions attended
P1	F	40–50	Mild	6
P2	F	20–30	Mild	2
P3	F	30–40	Moderate	4
P4	F	50–60	Moderate	5
P5	F	50–60	Moderate	3
P6	F	18–20	Severe	6
P7	M	20–30	Moderate	4
P8	F	50–60	Moderate	5
P9	M	50–60	Moderate	6
P10	F	50–60	Moderate	3
FM1	M	30–40	NA	4
FM2	F	20–30	NA	5
FM3	F	18–20	NA	1
FM4	M	18–20	At risk	2
FM5	F	20–30	At risk	3

($n = 2$), moderate ($n = 7$), and severe ($n = 1$) MJD. A diagnosis of MJD was confirmed by the MJD Foundation¹ based on a molecular blood test or a neurological assessment coupled with “at risk” status. Severity classification reflects stages of progression for all degenerative ataxias (Klockgether et al., 1998) and was based on neurological and functional assessments that included the Scale for the Assessment and Rating of Ataxia (SARA) (Schmitz-Hubsch et al., 2006). All participants spoke a Yolŋu language as their first language and were members of the same extended Yolŋu family. Participants with mild and moderate MJD used dysarthric speech to communicate. The remaining participant used multi-modal communication strategies to participate, including vocalizations and gesture (interpreted by family members). Participants had limited to no experience with formal AAC systems in English. Participant characteristics are presented in Table 1.

The first author and principal Yolŋu researcher carried out purposeful sampling to invite all Yolŋu living with MJD to participate. Opportunistic sampling was used to invite family members and close communication partners cohabitating with or visiting Yolŋu living with MJD at the time of the research to participate. The first author, together with Yolŋu researchers, met with eligible participants in person and explained the study orally in the participant’s language of choice. Participants were given the opportunity to ask questions and contact researchers directly regarding participation (rather than having to decide during the first meeting), to accommodate Yolŋu cultural communication protocols and avoid gratuitous concurrence (Cass et al., 2002). Written consent to participate was obtained at the beginning of the study; oral consent was re-confirmed before each session and by reading body language throughout all phases of the research.

Setting

The research was conducted in remote and regional Northern Territory, Australia. Research sessions were held

where participants felt the most comfortable, usually outdoors (i.e., sitting at a beach where they feel a spiritual connection).

Research design

The three inter-related studies are underpinned by qualitative-dominant, concurrent, transformative mixed methods research design (Creswell, 2009; Johnson et al., 2007). However, only qualitative research methods were used to develop Yolŋu AAC system prototypes in this study (initial quantitative and qualitative methods were used to determine core vocabulary in Study 2, see Amery et al., *in press*). Qualitative methods enabled culturally responsive, in-depth exploration of the cultural and linguistic considerations involved in Yolŋu AAC system design.

A Yolŋu metaphor, *Gulaka-buma* (“harvesting yams”) was identified toward the end of analysis of Study 2 (Amery et al., *in press*) and used in this current study (Study 3) to represent and share the findings and research process in a culturally responsive way that centered Yolŋu voices and worldview. Relevant aspects of the metaphor, *Gulaka-buma* (“harvesting yams”) are presented within the core vocabulary findings (Amery et al., *in press*). Additional elements of the metaphor relevant to the design of the AAC system prototypes are presented in this paper.

Participatory action research (PAR) was the dominant methodological framework (Baum et al., 2006) and involved successive cycles of planning, action, observation, and reflection with researchers and participants in an interactive and empowering process of collaborative enquiry (Baum et al., 2006; Walter, 2009). Power was intentionally shared between researchers and participants so that Yolŋu participants felt comfortable becoming active reflective researchers.

The theoretical paradigms Critical Theory and Social Constructivism informed this research, with a focus on relationships and understanding that knowledge is socially constructed (Hyter, 2014). Decolonizing and Indigenist research methodologies also underpinned the research design (Martin & Mirraoopa, 2003; Rigney, 1999; Smith, 2012). Indigenist research is carried out by Indigenous people, with Indigenous people, for the purposes of contributing to Indigenous peoples’ struggle for self-determination (Rigney, 1999). Decolonizing research specifically acknowledges the historical and ongoing colonial impacts and practices of researchers and institutions on Indigenous peoples, languages, and cultures, and, in so doing, challenges the inherent power imbalances through all stages of research (Smith, 2012).

Yolŋu and Balanda researchers collaborated in this culturally responsive research with the intent of contributing to the Yolŋu struggle to keep their languages strong. This was accomplished by continuing to communicate in Yolŋu languages when using AAC. Researchers were responsive to Yolŋu preferences and enacted principles of effective research as determined by the Yolŋu research organization, Yalu Marŋgithinyaraw (2012), whose principles include

¹MJD Foundation is a charitable organization that supports Aboriginal people with MJD and their families across the Northern Territory and Queensland. <https://mjd.org.au/>.

employing Yolŋu researchers, being flexible, working in Yolŋu languages, and learning through Yolŋu pedagogy.

Ethical approval for this study was received from Menzies School of Health Research with reciprocal ethics approval from Charles Darwin University.²

Research team

The first author was a non-Aboriginal SLP pursuing a Ph.D. who was familiar with formal AAC systems and had a family history living in Arnhem Land. She collaborated with five Yolŋu researchers employed through the MJD Foundation (see footnote 1). Yolŋu researchers had limited to no experience with formal AAC systems but their cultural and linguistic expertise ensured relevant, ethical, and culturally congruent processes and engagement through all stages of the research. A sophisticated kinship system and clan structure framed all interactions within the context of the study. Selection of Yolŋu researchers was based on their culturally appropriate kin relationships with the principal Yolŋu researcher (i.e., no avoidance relationships that prohibit direct interaction) as well as clan relationships with participants, to enable collaboration and trust. Other essential criteria included *ŋayaŋu manymak* (“having a heart for the research”), confidence with bilingual oral communication, and senior cultural knowledge and/or relevant skills and work experience in health, research, interpreting, or other intercultural work. Bilingual literacy was desired but not essential. Additional support was provided by a Yolŋu language teacher and researcher (see footnote 1) and Yolŋu elders and cultural advisors who contributed to analytical discussions in opportunistic and convenient ways.

Materials

A range of low-tech resources were developed for use in activities to explore Yolŋu considerations for AAC system design. These included (a) laminated cards with Yolŋu and English letters, Yolŋu syllables (initial, medial, and final), and words from the Yolŋu core vocabulary developed in Study 2 (Amery et al., *in press*); (b) different-sized paper grids with blank spaces; and (c) assorted pictures of familiar everyday objects (e.g., flour, knife, car, bag) and actions (e.g., make, cook, carry, fishing). Resources and AAC system prototypes were developed using Yolŋu language keyboard software,³ Microsoft Word, and Boardmaker Version 6.⁴

²Traditional knowledge and Aboriginal cultural heritage shared and presented in this research, including Yolŋu language and the Yolŋu metaphor, are corporately owned and retained by each participant and other members of their Clan Nation.

³Yolŋu language keyboard software and interfaces, available from the Australian Society for Indigenous Languages. See <https://ausil.org.au/resources/>.

⁴Boardmaker Version 6 is an AAC computer software program with a set of Picture Communication Symbols (PCS) developed by Mayer-Johnson. See <https://goboardmaker.com/>.

Pages were printed and modified with scissors, glue, and sticky tape.

A SmartLav+⁵ lapel microphone, extension cord, and iPad mounted on a tripod was used to video record sessions. Mobile phones were used for photos and audio recordings. When participants did not consent to recording sessions, the first author wrote detailed session notes. All written data were uploaded and analyzed using Nvivo 12. (QSR International Pty Ltd., 2019).

Procedures

Data collection

A total of 24 collaborative participatory action research data collection sessions were carried out to develop Yolŋu AAC systems from “the ground up,” that is, they were guided by Yolŋu preferences, language, culture, and worldview, rather than modifying existing AAC systems. Sessions ranged from individuals meeting with researchers, to large group sessions with up to eight participants and four researchers. Participants were involved in one to six research sessions, with an average of four sessions each (see Table 1). Sessions ranged from 30 min to 2 h and often included refreshments. Participants engaged in research activities based on their energy, fatigue, interest, and willingness, or *ŋayaŋu* (“inner spirit feeling and overt interest”). Group activities were optional and commenced when participants were ready. This approach helped minimize feelings of shame, embarrassment, or being singled out (Amery et al., 2020).

Researchers conducted data collection sessions collaboratively with participants, co-facilitating, participating in, and observing actions. Sessions involved various activities and related discussions to develop AAC system prototypes and explore Yolŋu linguistic and cultural considerations. Participants were asked to (a) name Yolŋu letters, sounds, and syllables and read whole words or identify from multiple options; (b) group pictures/words that go together; (c) construct their own AAC boards; (d) identify core vocabulary pictures in a grid and provide visual and verbal cues to other participants to locate symbols; (e) generate spontaneous sentences from Yolŋu word and picture cards to express in prototype systems; and (f) draw their own suggested symbols when adding fringe vocabulary. These activities provided opportunities to (a) model how AAC prototypes could be used; (b) assess whether Yolŋu sentences could be naturally expressed; (c) test and validate the initial Yolŋu core vocabulary with spontaneous sentences; (d) add words to fringe vocabulary pages; and (e) identify language and cultural considerations through real-world examples and discuss how to respond to them. Similar activities are often used in informal literacy, language, and AAC assessment processes and system trials by SLPs (Beukelman & Mirenda, 2013). Existing AAC research has involved participants drawing symbols (e.g., Draffan et al., 2015; Karal et al., 2016) but not constructing AAC boards.

⁵The SmartLav+ is a broadcast-grade wearable microphone product of Rode, Silverwater, NSW, Australia, <http://www.rote.com/microphones/smartlav-plus>.

Researchers met for reflective and analytical oral group discussions after and between sessions to discuss suggestions and make decisions related to modifying prototypes and new iterations for successive sessions. The first author wrote detailed notes and analytical memos and made reflective research journal entries about research planning, progress, challenges, and opportunities.

Words and symbols related to the core vocabulary and other everyday Yolŋu activities were arranged in various layouts during cycles of prototype development. Two iterations of a Yolŋu alphabet board, four iterations of a Yolŋu core word board, five iterations of a core (words) and fringe vocabulary (pictures) system, and three iterations of the core (pictures) and fringe vocabulary (pictures) system were developed.

Data analysis

Written data were analyzed using Nvivo 12 (QSR International Pty Ltd., 2019). The first author coded data using gerunds or “-ing” words to focus on the research team’s actions, thinking, reflecting, and planning processes (Charmaz, 2008; Saldaña, 2009). Simultaneous coding, applying more than one descriptive code, was used as necessary (Saldaña, 2009). To demonstrate the initial coding process, the following is an example of an analytical memo written after a researcher discussion and provisionally tagged with the following codes: “spending many hours,” “searching and selecting from database,” “looking for something similar,” “modifying Picture Communication Symbols,” “making symbols recognizable,” “including context of person signing,” “working with an illustrator,” and “making symbols accurate:”

I did some work yesterday with Researcher 3 following up the suggestions from our session with Participant 8 and Family 4. It was quite tedious spending hours on Boardmaker trying to modify symbols. We just did the best we could, trying to find something similar, enough that it might be recognizable, or at least an example to show participants. It highlights the need to work with an illustrator to make appropriate symbols i.e., with hands facing the right way. Having the context of the whole person doing the action was important. Not just a picture of the body part, but having a person doing the sign. Researcher 3 said “Make a note for when we get an illustrator to make a cartoon, to make the symbols right. Flip hand around on *wāwa* (“older brother”), *yapa* (“older sister”) and *yukuyuku* (“younger sibling”). Also, for *gurruŋ* (“woman’s son in law”) the elbow needs to be higher, like aunty was doing.”

Through a culturally congruent process of collaborative discussion, initial codes were discussed with Yolŋu researchers, modified, and grouped to identify key themes related to cultural considerations, and changes and decisions involved in developing the prototypes. Key themes were also organized according to typical aspects of AAC to share with SLPs and AAC practitioners. In the final stages of analysis, analytical coding, key theme development, reflexivity, and ongoing oral discussions led to the development of a Yolŋu metaphor to represent and share the research process and outcomes in a culturally responsive way.

Trustworthiness

The trustworthiness of qualitative analysis is determined by its credibility, dependability, transferability, and authenticity (Elo et al., 2014). To ensure the research was respectful and useful from a Yolŋu perspective, the research team worked together and maintained strong, mutually respectful relationships. Research team members followed Yolŋu cultural protocols, prioritized working in Yolŋu languages and were guided by cultural advisors and elders. Final key themes and the Yolŋu metaphor were checked, confirmed, and shared with participants before relevant stakeholders.

From a non-Aboriginal research perspective, triangulation of research methods, data sources, and transparent coding practices were used with a clear audit trail of research notes and memos to document the research process, key theme development, and identification of the Yolŋu metaphor. The first author kept a research journal and participated in discussions with Yolŋu researchers to reflect on the impact of different cultures and worldviews.

Results

Through this study, a total of four Yolŋu AAC system prototypes were developed to suit Yolŋu with varied Yolŋu literacy confidence. To achieve this, cultural and linguistic considerations related to different aspects of AAC design were identified. A Yolŋu metaphor was also identified by Yolŋu researchers to represent the research process and findings from a Yolŋu worldview. In the following discussion of the results of the study, aspects of the metaphor are shared first to privilege Yolŋu voices and perspectives. Findings related to traditional aspects of AAC system design are then presented, including details of the 4 Yolŋu AAC system prototypes, and 13 key themes with design considerations related to vocabulary representation, layout, and access.

A Yolŋu metaphor for the research

The Yolŋu metaphor *Gulaka-buma* (“harvesting yams”) was identified by Yolŋu researchers towards the end of the analysis to represent and share the research process and findings using a familiar conceptual framework. One aspect of the Yolŋu metaphor *Gulaka-buma* (“harvesting yams”) considered to be of particular relevance to the development of AAC prototypes related to *Gantjiŋ djäma* (“digging a bigger hole for yourself”). This concept is about positioning yourself and being strategic about where and how you focus your energy, “You have to dig a bigger hole for yourself to position yourself so that you can keep digging deeper” (Yolŋu Cultural Adviser 1). A key realization of the research team was acknowledging the need to be strategic about which aspects of system design to focus on to make the most of their time together.

Another key component of the metaphor was *Gaykarrangum* (“the way that is clear of obstacles”). As a research team, we reflected that an important aspect of working in a culturally responsive collaborative way was to

work around conflict and complex issues, following the decisions and core values around which we had consensus, and trusting that solutions to challenges would be identified later: “Dig this side, not that side because I can see there are roots blocking the way, we should dig this side. This way is clear, then you can see the food” (Yolŋu Cultural Advisor 1). After several sessions, we started to see patterns in the data about what was important to Yolŋu. We focused on patterns and decisions for which we had attained consensus, incorporated those preferences for use in the prototypes, and left other aspects for discussion at a future time.

A third component of the metaphor related to *Dholkum yiŋarray'* (“covering and marking your findings” and coming back to them later). As a research team we were pleased with our progress. We reached consensus on several aspects of AAC system design, and it was time to start spending more time learning and practicing using the prototypes in conversation to test them. The prototypes evolved; initial versions were not perfect, but we could keep using them, personalizing them, and learning together for many more seasons. Sometime when we were out hunting for yams, we had to cover over where we had been digging and mark that place so that we could come back to it later, “The pigs are coming all the time. Leave it, we’ll cover it up. I’ve marked it. We’ll come back another day when we’ve got more time and everything we need” (Yolŋu Cultural Advisor 1). Photographs related to this metaphor, with first-person reflections and additional details, are presented in the Appendix, and can also be found in Amery et al. (in press).

The Yolŋu AAC system prototypes

Four Yolŋu AAC system prototypes were developed concurrently: an alphabet board (Prototype A), a core word board (Prototype B), a comprehensive communication book with words for core vocabulary and symbols for fringe vocabulary (Prototype C), and a comprehensive communication book with symbols for core and fringe vocabulary (Prototype D). Vocabulary for Prototypes B, C, and D was obtained from the Yolŋu core vocabulary developed in Study 2 (Amery et al., in press), with additions from vocabulary-based activities that occurred during later cycles of the current study. Vocabulary items were predominantly organized in a flat structure (one to two levels of taxonomy), with cultural categories for *Gurruŋu* (kinship system), *Mälk* (“skin names”) and *Bäpurru* (“clan groups”) presented first, followed by words in first-sound consonant groups, place names, English words and alphabets. Prototypes A and B have one level of taxonomy, Prototype C has two levels, and Prototype D has three levels. See Figures 1–4 for photos and descriptions of the prototypes.

Key themes presenting cultural and linguistic considerations

Thirteen key themes were identified to guide Yolŋu AAC system design from a Yolŋu perspective: four related to vocabulary (Supplemental Table 2); five related to layout

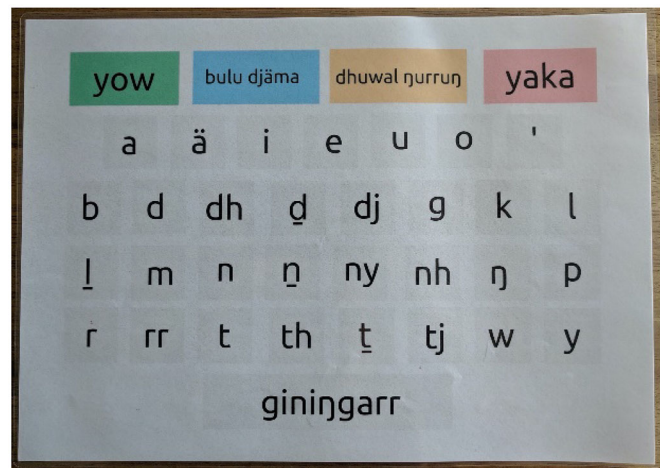


Figure 1. Yolŋu AAC system prototype A. Yolŋu alphabet board with English alphabet on reverse side, same format. Top row presents cells for message editing. Second row presents Yolŋu vowels in “short and long pairs.” Rows 3 to 5 present consonants in alphabetical order. Final row cell “button” to indicate space bar.

(Supplemental Table 3), and four related to access (Supplemental Table 4). The sections that follow describe each theme, including cultural and linguistic considerations and representative quotes and examples from Yolŋu languages.

Representing vocabulary in Yolŋu AAC systems

The following were the key themes representing vocabulary: Assessing Literacy Confidence and Capacity, Choosing and Modifying pictures, Drawing on Cultural Knowledge and Experiences, and Creating Recognizable Symbols.

Participants showed varied confidence in their reading and writing of Yolŋu languages. Approximately half of the participants demonstrated limited or developing Yolŋu literacy, while the other half demonstrated competent-to-confident Yolŋu literacy (see Supplemental Table 1). Researchers acknowledged that Yolŋu literacy impacted participant confidence and capacity to access AAC: “She has good literacy, Yolŋu and English. For everyone else, without good literacy, it takes time, it’s harder” (Yolŋu Researcher 1). Overall, regardless of their level of competence, participants were keen to improve their Yolŋu literacy, seeing benefits in developing literacy skills beyond use of AAC: “It’s good, even I’m learning more about Yolŋu spelling through these (activities)” (Yolŋu Researcher 3). The four AAC prototypes were designed to accommodate the range of competence among participants. The Yolŋu and English alphabets were included in all prototypes for modeling and improving literacy, and vocabulary was always represented in words (with accompanying pictures in Prototypes C and D). Additionally, categories and vocabulary items were all presented in alphabetical order for consistency across languages, literacy learning and assisting participants to locate vocabulary.

Participants considered that cartoon pictures were more appropriate than photographs or line drawings to represent vocabulary. Many logistical and cultural barriers were

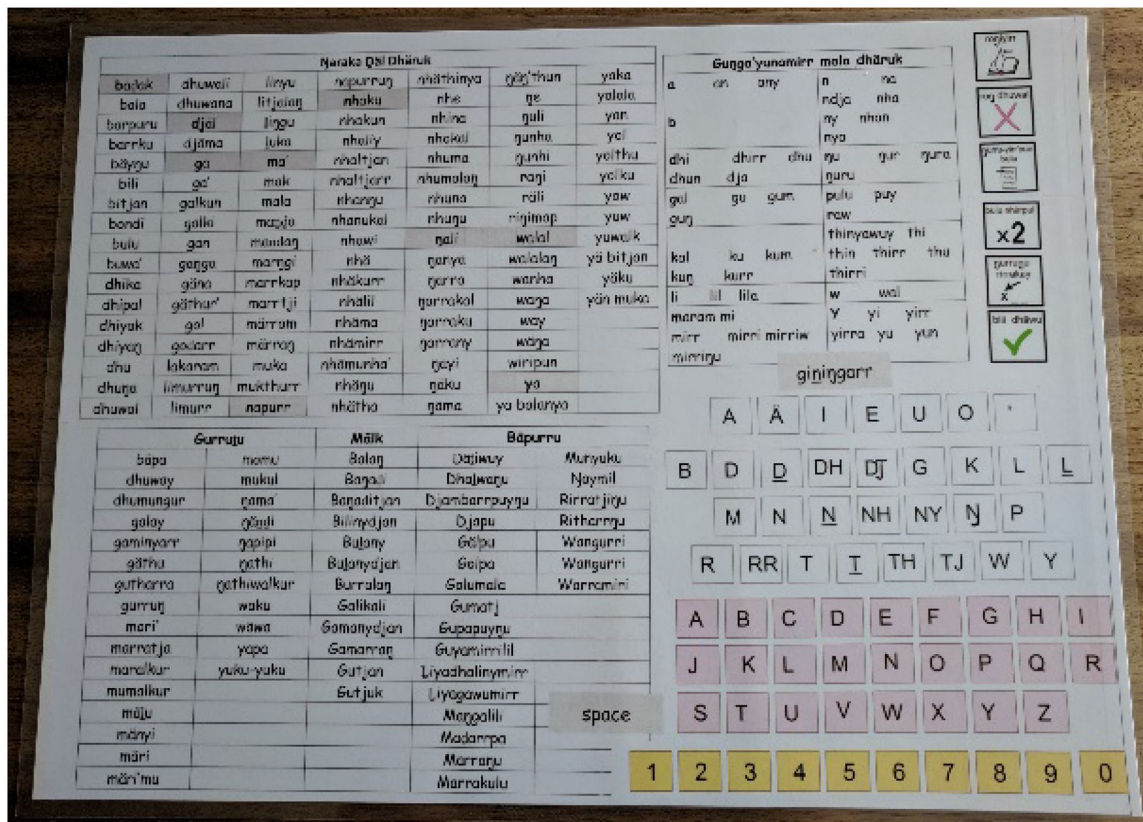


Figure 2. Yolŋu AAC system prototype B. Yolŋu core word board with core vocabulary represented in words presented in alphabetical order, top left. Suffixes presented top right, with far right side panel with cells for message editing. Yolŋu core categories “kin relations,” “skin names,” “clan names” presented bottom left, and Yolŋu and English alphabets with numbers presented in bottom right.

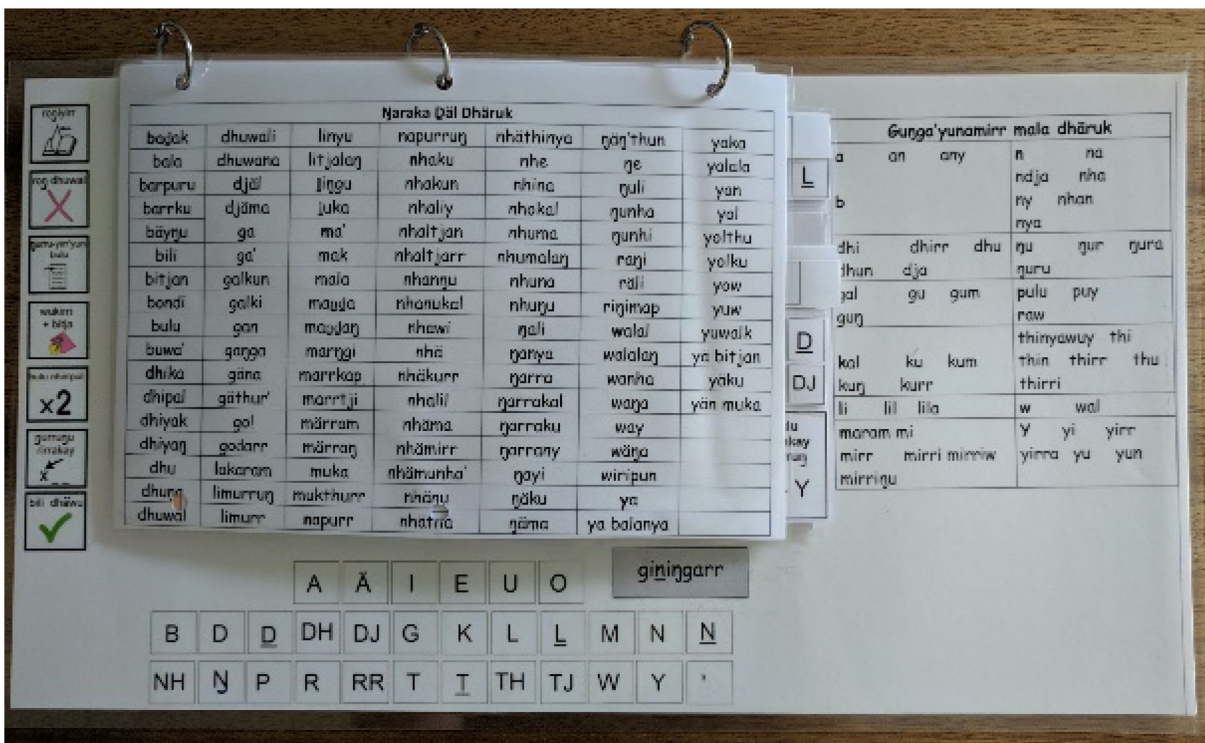


Figure 3. Yolŋu AAC system prototype C. Yolŋu comprehensive communication book with core vocabulary represented by words on front center page. Under pages present Yolŋu core categories in words, fringe vocabulary represented by symbols in alphabetical sound letter groups/categories, and English words and alphabet. Left side panel cells for navigation and message editing, right side with Yolŋu suffixes and bottom panel with Yolŋu alphabet.

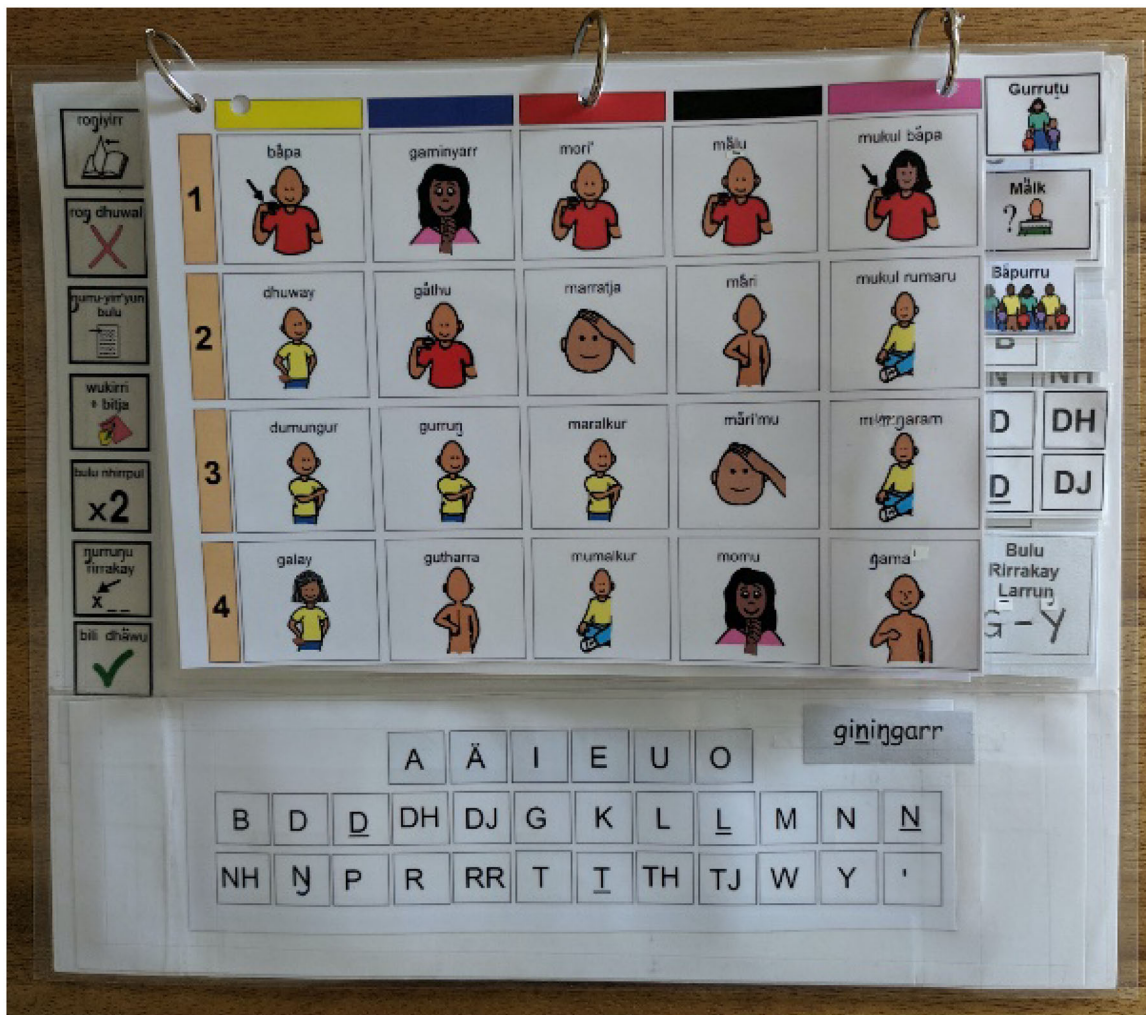


Figure 4. Yolŋu AAC system prototype D. Yolŋu comprehensive communication book with Yolŋu core categories represented by symbols, followed by core and fringe vocabulary represented by symbols in alphabetical sound letter groups/categories. Yolŋu suffixes, place names and English words represented by symbols presented on last pages with English alphabet. Left side panel cells for navigation and message editing and bottom panel with Yolŋu alphabet.

identified in finding appropriate people and places to photograph. A consistent set of visual symbols was considered beneficial in reducing visual fatigue. Participants were happy to use Picture Communication Symbols (PCS) (see footnote 4) which the researchers already had access to. Despite this, symbols suggested by Boardmaker software as correlated to concepts were rarely used because Yolŋu participants and researchers didn't perceive them to be a good representation of the Yolŋu concepts. Researchers searched for alternatives and modified existing symbols to be more culturally responsive. This had implications for both the development process and features of the AAC systems. Searching for alternatives and modifying existing symbols was time consuming and made reproducing the systems more difficult. Symbols within the software needed to be relabeled and new symbols added, to avoid challenges and inefficiencies in locating the same symbols again.

Existing symbols were rotated and combined, parts of symbols were erased, lines were added, and colors were changed. For example *go* ("come"/"give it") represented by the sign/gesture for "come," was modified so that the hand pointed down. The hand pointed up was seen to be

offensive. Symbolic patterns were also generated for possessive pronouns, for example *manḍa* ("they (two)") was represented by two people, and *manḍaŋ* ("theirs (two)") was represented by the same symbol with the addition of a culturally desired item (a fish), as in, "their (two) (fish)." Sometimes there was no appropriate PCS within the dataset and open-source images from the Internet were uploaded, such as for *latjin'* ("mangrove worm").

Cultural knowledge and experiences were used to generate new culturally recognizable representations of vocabulary concepts. For example, *bāpa* ("father") was represented by the Yolŋu sign for the kinship pair father/father's child. *Gutjan* (*Yirritja* moiety skin name for a woman) was represented by a woman with a white cockatoo to indicate *Yirritja* moiety. The word *dhu* ("will"/future tense marker) was represented by two fists, a well-known action from contemporary Yolŋu dances.

When participants generated their own symbols, story scenes were commonly drawn, inspired by recent cultural activities. These scenes were deemed to be a culturally responsive way to represent vocabulary, reflecting both familiar cultural experiences and using the familiar modality

of storytelling for communication. One example was the symbol drawn for the word *rirrakay* (“sound”) added to fringe vocabulary during the hunting season for wild honey: “The sound is from that person calling out to that person.” The other person heard the sound, “Hey you!” (Participant 3); One person says, “there’s honey over here!” and the other person says, “there’s honey over here!” (Family member 2).

As with learning other symbols, participants needed to hear the narrative to recognize the symbol. One limitation was that story scenes with multiple components incorporated were visually complex. Additionally, some pervasive stories and symbols were used to communicate about many concepts (e.g., fishing, sun). While this repetition wasn’t inherently a problem, participants needed to be able to distinguish between concepts presented on the same page.

Yolŋu AAC system layout

Cultural and linguistic considerations that related to AAC system layout were represented in the following key themes: Creating a Flat Alphabetized Structure, Privileging Yolŋu Categories, Choosing a Grid Layout, Deciding on Size, and Incorporating Color.

As noted in discussions about representing vocabulary, participants also demonstrated narrative thinking and communicating when grouping words together. Said Participant 4, for example: “Flour, baking powder, baking soda, golden sirup, tea bags, billy can, container—they are all things you take to go hunting.” To enable Yolŋu AAC users to make multiple associations with vocabulary consistent with their worldview, the prototypes were designed with a relatively flat structure. Category groups were included for *gurrui* (“kin relations”), *malk* (“skin names”), *bapuru* (“clan names”), *gungayunamirr dhäruk mala* (“supporting words”), *wäŋa mala* (“remote communities”) and *Balanda dhäruk* (“English words”). All other words were arranged in alphabetized consonant groups, for example “d, ḍ, dh, and dj” as one group, so that all d-words were located in the same group, *D-mala dhäruk* (“D-group words”). Yolŋu core category groups were presented first to emphasize Yolŋu worldview, culture, and language for daily communication and literacy learning. When Yolŋu looked at the AAC prototypes, they instantly recognized fundamental Yolŋu vocabulary. A Yolŋu researcher explained why Yolŋu categories for kin and relational terms were presented first, to reflect the linguistic and cultural importance of relationships in daily life:

I am your mother’s child. My skin name is *Gutjan*, and my clan is *Gurruyŋu*. That clan name can take you to the place and imagine where that person is from. That’s how people are connected, through song-lines, kinship, skin names and clan groups. (Yolŋu Researcher 4)

Most participants were keen to learn and have access to a bilingual AAC system but acknowledged their priority was communicating in their first language: “I want you to do my tool in Yolŋu instead of English. Actually, no, I will learn both. First in Yolŋu, then I will learn English” (Participant 7). The English alphabet was included in all prototypes. A small number of English concepts were also included as fringe

vocabulary in the last pages of Prototypes C and D to complement and promote Yolŋu language use and literacy learning. One participant used the system including some English when she knew the Yolŋu word she wanted to say but not how to spell it. She used the English alphabet to spell the English translation, so that her communication partner could add the Yolŋu word to fringe vocabulary.

A traditional grid layout was used to support natural communication. When single photograph scenes were used to stimulate conversation, participants focused on the details of the photographs. In her Journal entry of November 20, 2018, the first author reflected, “I asked if they could try to use the photo to tell different stories, but I think they just looked confused and continued to talk about details of the photo.” Prototypes C and D have a left side panel for navigation, and a bottom panel with the Yolŋu alphabet. Yolŋu grammar was supported in all prototypes, but suffixes were presented differently in systems C and D.

AAC system prototypes did not exceed A3 paper size with all panels included. Grid size for AAC system Prototypes C and D were a bit smaller than A4 paper size, with 20 cells per page. This allowed almost all participants to access the AAC systems directly, “Yeah, this size is good so she can point to everything” (Yolŋu Researcher 1). With more than 20 cells per page, search time and fatigue increased. Use of AAC systems was greatly aided for participants with prescription glasses because of visual issues associated with the disease.

Cultural and linguistic significance of color in the design of the AAC system prototypes was also considered by the researchers. For example, the Yolŋu term *milukuminy* (“blue/green”) indicates no clear distinction between blues and greens in Yolŋu languages, and some Yolŋu clans are represented by flags of a particular color. Yellow, black, red, blue, and pink were selected as column markers in the grids of Prototypes C and D to support scanning access options. Background symbol color was used in Prototype D to differentiate core vocabulary from fringe vocabulary items in consonant groups. Most participants preferred colored symbols, which were used in all prototypes.

Accessing the Yolŋu AAC systems

Cultural and linguistic considerations related to AAC system access were represented in the following key themes: Trialing use of Grid Reference Markers, Modeling AAC Navigation Options, Considering Message Editing Action Cells, and Building a Role for Yolŋu Communication Partners.

Describing and orienting to grid locations by row or column was difficult for many participants because many concepts required for this task are absent in Yolŋu languages. Yolŋu Researcher 1 explained, “We have some words in our language, like *yarraṯa* (‘line’), *yarrupthun* (‘down’), *ŋurruŋu* (‘first’), *buraŋapungga* (‘middle’), *läy* (‘on the side’). But some of them we don’t really use, so it won’t make sense” (Yolŋu Researcher 1). Participants were able to learn to follow grid cues using numbers and colors. This was a new task for all participants. AAC Prototypes C and D have colors above the

columns and numbers 1 to 4 at the beginning of rows to increase access options for participants as disease symptoms progress.

Appropriate Yolŋu terminology was identified for AAC system navigation in prototypes C and D. These terms were modeled by researchers to demonstrate their meaning and use: *roŋiyirr* (“turn back”), *ŋurruŋulil bilmaraŋ* (“go back to the start”), *bulu rirrakay* [arruŋ] (“find more sounds”), *wukirriga bittja* (“write and draw a picture”). Message editing cells were also considered: *ŋurru-yirr’yurr bulu* (“start again”), *bilin dhäwu* (“finished my story”). Word editing cells were also considered to allow Yolŋu to make phonemic changes to words to construct grammatically correct sentences. Examples included *roŋ dhuwal* (“that letter/suffix/word was wrong”), *buwayakkum* (“delete”), *manapan* (“add”), *bulu nhirripul* (“that part again”) to duplicate the whole or part of a word. Phonemic changes occur for different Yolŋu verb forms and when adding suffixes to root words, owing to linear and non-linear morphology in Yolŋu languages (see [Supplemental Table 4](#)).

Participants and researchers suggested alternatives to accommodate phonemic changes, which involved either adding all variations as separate words to systems or Yolŋu communication partners intuitively modifying words. It was agreed that Yolŋu communication partners were more likely to intuitively modify words than use linguistic knowledge to modify sounds. Other instances where Yolŋu communication partners would be required to intuitively change words were also discussed, such as for the Yolŋu cultural practice of not saying aloud the name of a person who has recently died, or in some regions, words that sound like the name. This need arose multiple times during the research, when the words *marrtji* (“go”) and *walal* (“they (plural)”) were no longer spoken. Yolŋu Researchers discussed different options: “If you leave (*marrtji*) and (*walal*) on the list, family communication partners can easily think of another word” (Yolŋu Researcher 4). “If we leave it there, someone might say it. Best to cover it up. Make sure that word can’t be said. We need to find a way to not offend people” (Yolŋu Researcher 5).

With the current AAC prototypes, Yolŋu communication partners are responsible for modifying phonemes of some words to construct grammatical sentences and using an appropriate spoken word to substitute for written words temporarily out of spoken use.

In summary, a wide range of cultural and linguistic considerations were raised and discussed as they related to all aspects of AAC system design, including vocabulary representation, system layout and access. Various design solutions were proposed and trialed through the process of developing Yolŋu AAC system prototypes.

Discussion

This research involved a highly collaborative, intercultural, exploratory process to develop four Yolŋu AAC system prototypes for Yolŋu adults living with MJD. A characteristic feature of this research was the culturally responsive, strength-based approach to collaboration with participants through all stages

of AAC design. Yolŋu language, concepts, and pictures central to Yolŋu culture and identity, including *gurruŋu* (kinship system) and enjoyable activities prevalent in Yolŋu life (e.g., going hunting), were used to explore aspects of AAC design. These resources and research activities enabled participants to engage in the research, feel confident and connected to their culture, and share their opinions through stories. Other studies in AAC development in non-English languages have also used PAR (e.g., Draffan et al., 2015), user-centered design (Hervás et al., 2020), or human-centered design (Daems et al., 2016). Collaborative and user-centered design approaches ensure AAC systems are usable and useful, whereas PAR also aims to challenge existing power dynamics. In existing AAC research, these approaches have enabled collaboration with people living with complex communication needs but evidence of research processes to ensure culturally responsive research is limited. Although use of metaphor in research is common practice with Yolŋu (Marika-Mununggiritj & Christie, 1995), and AAC development in Mandarin has used cultural metaphors to develop culturally appropriate icons and associations (Baker & Chang, 2006), identifying a metaphor to represent and share research processes and outcomes was a new way of presenting AAC research.

Clinical implications

This research substantiates findings from previous studies demonstrating that linguistic differences between languages have implications for vocabulary representation, layout, and access (Baker & Chang, 2006; Mngomezulu et al., 2019). Additionally, the common practice of code-switching by bilingual speakers requires particular consideration in the design of multilingual AAC systems (Tönsing et al., 2018).

In this study, Yolŋu AAC system prototypes were designed to consider the physical limitations caused by MJD and to incorporate not only Yolŋu language but also Yolŋu culture and worldview in the whole of the AAC system design. Existing research has demonstrated the significant impact of culture on the perception and use of graphic symbols in AAC, including the need to adapt icons to consider cultural associations (Andres, 2006; Baker & Chang, 2006; Karal et al., 2016). This study has gone further, using examples for vocabulary organization, system layout, access, and the development process to demonstrate that cultural influence is not restricted to representation of vocabulary but is relevant to all aspects of AAC.

The layouts of Yolŋu AAC system prototypes were designed to accentuate the centrality of identity and relationships for Yolŋu, and enable users of AAC systems to continue to communicate authentically—in a relational way, allowing expression of multiple perspectives through narratives (van Gelderen & Guthadjaka, 2017). Vocabulary in the Yolŋu AAC system prototypes were organized in a relatively flat structure, with cultural categories presented first to emphasize relationships in Yolŋu culture and worldview. This is different to most AAC grid displays which arrange vocabulary by category, event or word class (Light et al., 2019). Other AAC systems in languages other than English have

used existing AAC system architecture (Andres, 2006). Flattening metadata structures enables Yolŋu to arrange and use resources for themselves, in their own contexts, in ways that enhance the creative connecting processes in Yolŋu knowledge making:

The way in which the metadata [of words] are traditionally sequestered into fields to facilitate searching actually prevents those flexible political connections between things and names from being real in the database and gives priority to a Western objectivist ontology... Words, in an Aboriginal language, have their power in the work of knowledge production, by virtue of their potential relatedness to any of the different fields in the metadata structure. In other words, they attain their power precisely because they resist that categorization. (Christie, 2005, p. 56)

Linguistic and cultural considerations for AAC access were also identified. Visual and auditory-visual scanning methods using grid reference markers for alternative access rely on specific vocabulary and ways of thinking and knowing. Linear and group-item scanning was a foreign activity and way of thinking for most participants who did not have the Yolŋu vocabulary to describe layouts in this way. Alternative access methods such as scanning are slower, less efficient and more cognitively demanding than direct access (Fager et al., 2012). For Yolŋu living with MJD, it also required a foreign way of thinking. While Yolŋu were able to learn scanning skills through a culturally responsive co-design process, identifying linguistic differences and worldview assumptions in AAC access were significant considerations for AAC system design and implementation with Yolŋu families.

Findings from this research also confirm the importance of considering all access and participation barriers in AAC assessment and implementation (Beukelman & Mirenda, 2013). Physical symptoms, including impaired fine motor movements, but particularly vision impairment and fatigue impacted participants' ability to access the Yolŋu AAC system prototypes. Good management of vision impairment and prescription glasses greatly aided participants' ability to engage with the AAC systems.

Limitations and future directions

While a number of design variables and cultural and linguistic considerations were identified and discussed through this research, collaborative exploration of features was not exhaustive or systematic. Ongoing collaboration with linguists and Yolŋu language and cultural advisors is required to further explore expression of full Yolŋu grammar.

Another limitation of this research was the small number of participants. Only 10 Yolŋu with MJD, along with five of their family members participated, compared, for example, to a study by Karal et al. (2016) that explored vocabulary representation for a Turkish symbol set that involved consultation with over 1000 individuals. In comparison to other languages of the world, there are relatively few speakers of Aboriginal Australian languages. Exploration of the AAC system prototypes with other Yolŋu may provide additional insights and considerations for AAC system development; however any AAC research with Indigenous Australians is likely to be designed for small participant numbers. It is also possible

that family members were more interested in formally participating in this research if they felt confident in their literacy skills. The proportion of family members with confident literacy skills is unlikely to be representative of Yolŋu communication partners overall.

Boardmaker Version 6 was not able to integrate with the Yolŋu keyboard (see footnote 3), lacked PCS for culturally relevant vocabulary, and existing symbols needed modification to be culturally responsive. Other AAC research in languages other than English has also found limitations with PCS (Nigam, 2006). While use of modified PCS in Yolŋu AAC system prototypes may have been functional in the interim, the iconicity, learnability, and social validity of the selected symbols requires further user-testing. Participants expressed interest in working with Indigenous illustrators and graphic designers to generate culturally appropriate and consistent symbols.

In terms of future research, the priority must be with Yolŋu living with MJD and their family members for ongoing user-testing to continue to personalize, validate, and expand fringe vocabulary in the existing AAC systems and support use of the AAC systems in everyday communication contexts. Research is needed to examine the learnability and social validity of modified PCS (see footnote 4) as well as pragmatic use of the AAC systems and their potential to increase communication opportunities for Yolŋu living with severe MJD. Other visual spatial aspects could also be investigated to increase communication efficiency. For example, future research could consider whether clustering symbols with background color cues would still increase visual processing speed (Light et al., 2019) for Yolŋu with visual issues associated with MJD.

A long-term research goal is to explore the expansion of these low-tech paper prototypes to high tech systems. There has been keen interest from participants in seeing these options eventuate. Additionally, future collaborative research could explore use of the Yolŋu AAC systems by other Yolŋu adults with acquired communication disorders or Yolŋu children, to support Yolŋu language and literacy development.

Participatory methods used in this research, challenging existing power dynamics and enabling creative, collaborative and culturally responsive co-design processes, can also inform future studies that are needed in non-Western cultural contexts, particularly rural, remote, and resource-poor environments.

Conclusion

Four Yolŋu AAC system prototypes were developed through successive cycles of planning, action, observation, and reflection in this highly collaborative, intercultural research. The Yolŋu metaphor *Gulaka-buma* ("harvesting yams") was used to represent and share the research process and outcomes, and numerous unique linguistic and cultural considerations for Yolŋu AAC system development were identified. Yolŋu language and culture influenced vocabulary representation and symbol selection. The relational, performative, multiple-perspective and narrative ways of knowing and communicating by Yolŋu resulted in a relatively flat alphabetized system

layout with several cultural categories presented prominently. AAC system access was also influenced by Yolŋu languages, culture, and worldview, as well as by participants' symptoms of MJD. Future research is needed to evaluate Yolŋu AAC system prototype use and their potential to improve communication opportunities for Yolŋu with severe MJD. Other researchers and AAC practitioners working with Indigenous peoples or multicultural populations with complex communication needs may be inspired by the findings in this research to collaboratively create multilingual AAC systems that incorporate and respect diverse cultures.

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Appendix

Gulaka-buma (“harvesting yams”)

This metaphor was identified by Yolŋu researchers to share the process and outcomes of developing Yolŋu AAC system prototypes. Aspects of the metaphor that were particularly relevant to development of the prototypes are described below.

Gaḍaman Yolŋu (“working with wise, knowledgeable people”)

That knowledgeable person knows where there are yams—if it’s the right season, looking at the color of the leaves and where the sand is soft to dig. That wise person knows where to go, how far, what to bring, what to look for. They already know where the yams are. They go there to get yams. (Yolŋu Researcher 1).



We worked together with knowledgeable and experienced people to develop these Yolŋu AAC system prototypes: Yolŋu living with MJD and their families; Aboriginal community workers; older wise Yolŋu cultural advisors and linguists, speech-language pathologists, and researchers.

Yaka Bakmaranŋ (“don’t break the vine”)

When you are digging you have to keep following that vine. You follow that vine right to the end where you see the head (of the yam) and start digging. If you break the vine, you won’t be able to find the yam. If you cut it half-way, then you are lost, the vine will go away, and you won’t be able to see where the yam is. (Yolŋu Researcher 1)



We worked systematically, following principles of doing research with Yolŋu, and drawing on core vocabulary research methodology. We always kept our purpose in mind, that we were selecting vocabulary and designing AAC systems for Yolŋu living with MJD.

Baḍak Belam (“keep digging to the full extent”)

“She had a solid, heavy duty, pointy yam stick that she used with tenderness. She got it through careful digging” (Yolŋu Researcher 2). “You have to keep digging through to the end, then you get it. You pull the yam with the roots on it, then you know they’ve gone right down” (Yolŋu Researcher 1).



We didn’t rush or just choose any words to make some communication boards. We carefully considered each word and many factors. We worked together systematically so that everyone could see that we followed a rigorous and respectful process. We wanted the AAC systems to be recognizable to Yolŋu, and for Yolŋu to use them to communicate naturally with their family in their own languages.

Gändjiŋ Djäma (“digging a bigger hole for yourself”)

“When you dig, you start to see how big the yam is, what type, where it goes, what colour, how old it is” (Yolŋu Researcher 1). “You have to dig a bigger hole for yourself to position yourself so that you can keep digging deeper. Use your arm as a measure, if the hole comes up to your arm, you have to make the hole bigger” (Yolŋu Cultural Advisor 1).



When we started to talk together and develop the AAC systems, we realized just how many aspects there were to think about. We were strategic about which issues we focused on, and which issues we left for a future time, so we made the most of our time together and included everyone’s input, working together to agree.

Gaykarrangum (“the way that is clear of any roots or obstacles”)

“Dig this side, not that side because I can see there are roots blocking the way, we should dig this side. This way is clear, then you can see the food” (Yolŋu Cultural Advisor 1).



As we discussed and developed the Yolŋu AAC system prototypes, we started to hear similar stories and see patterns about what was important to Yolŋu about the AAC systems. We incorporated these ideas and preferences so that we can use the prototypes now, and we will keep thinking and talking about aspects that still need more work.

***Dholkum Yiŋarray'* (“cover and mark your findings, come back to it later”)**

“We’ll leave it now. The pigs are coming all the time. Leave it, we’ll cover it up, I’ve marked it, and come back another day when we’ve got enough time and everything we need” (Yolŋu Cultural Advisor 1).

It was good, I learned a lot. Like, it was getting late, we needed to take those people home. But we can cook up what we got on the fire, have a taste and go hunting again tomorrow and try and find some more. (Yolŋu Researcher 1)



We have worked hard in this research. We have learned together and developed workable AAC system prototypes. Everyone was happy with them. It was time to stop talking about what could still change and start spending more time using them in conversation to learn. They are not perfect, but we can keep using them, personalizing them, and learning together for many more seasons.

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