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The Language and Communication Attributes of Graphic Symbol Communication Aids – A Systematic Review and Narrative Synthesis

Simon Judge[1,2], Nicky Randall[1,2], Juliet Goldbart[1], Yvonne Lynch[1], Liz Moulam[1], Stuart Meredith[1], Janice Murray[1]

Faculty of Health, Psychology and Social Care, Manchester Metropolitan University, Manchester, UK.

Barnsley Assistive Technology Team, Barnsley Hospital, Barnsley, UK.

Simon Judge

Assistive Technology Team, Barnsley Hospital, Gawber Road, Barnsley. S75 2EP. UK

01226 43 2159, Simon.judge@nhs.net

ORCID: https://orcid.org/0000-0001-5119-8094

The Language and Communication Attributes of Graphic Symbol Communication Aids – A Systematic Review and Narrative Synthesis

Background: Symbol communication aids are used by children with little or no intelligible speech as an Augmentative and Alternative Communication strategy. Graphic symbols are used to help support understanding of language and used in symbol communication aids to support expressive communication. The decision making related to the selection of a symbol communication aid for a child is poorly understood and little is known about what language and communication attributes are considered in this selection.

Aim: To identify from the literature the language or communication attributes of graphic symbol communication aids that currently influence AAC practice.

Method and Procedure: A search strategy was developed and searches were performed on a range of electronic databases for papers published since 1970. Quality appraisal was carried out using the CCAT tool and papers rated as weak were not included in the review.

Results: Eleven studies were included in the review reporting data from 66 participants. Weaknesses were identified in most studies that would limit the validity of the results for application to practice.

Included studies investigated aspects of vocabulary organisation and design, the process of vocabulary selection, and the choice of the symbol system and encoding method. Two studies also evaluated innovative communication aid attributes.

Conclusions: Information from studies reported in the research literature provides a sparse source of information about symbol communication aids from which clinicians, children or family members may make informed decisions.

Keywords: AAC; Augmentative and Alternative Communication Aids; Graphic Symbols; Communication Aids

Symbol communication aids are used by children with little or no intelligible speech and the positive effects of use are well documented [1]. Symbol communication aids are one of the range of Augmentative and Alternative Communication (AAC) strategies. AAC supports the communication of individuals with speech, language or communication difficulties. AAC strategies include those that support the understanding of language and also those that support expressive communication through the use of tools and techniques such as signing, partner assistance, and powered and paper based communication aids. Graphic symbols are used by some people to represent language. Graphic symbols can be used both to support the understanding of language and also within symbol communication aids to support expressive communication

In this review we are interested in the impact language and communication attributes have on decision making about which symbol communication aid to use. We define language and communication attributes as any feature of the symbol communication aid which directly impacts the development of and construction of language by the individual using the aid or otherwise facilitates the production of communicative utterances [2]. As an example the aesthetics of the device may significantly impact on the use of the device by the individual but impact on the communicative output in an indirect way whereas the arrangement of words on the screen of a device directly impacts on the user's ability to construct language to be used for expressive communication.

Symbol communication aids can be conceptualised as physical entities that display AAC vocabularies. Powered (voice output) communication aids include AAC software which allows interaction with the vocabulary package and generally displays it on a screen. In the case of unpowered AAC, the physical device would most likely be paper.

The vocabulary package used within a symbol communication aid is a listing of words or concepts with associated graphic symbols that is arranged in some way on the communication aid and which supports the user in creating communicative utterances. A wide range of different vocabulary packages are available in practice (an example is seen in Figure 1). Most typically these packages arrange symbols in a grid matrix on a page or pages of a book, or in virtual pages within software on an electronic device [2].

INSERT FIGURE 1 HERE

Initial symbol communication aids were pen-drawn on paper as communication boards and books. Later systems developed using microcontrollers and fixed displays with text or speech output before the introduction of the most recent generation of devices which use microprocessors/computers and have screens allowing dynamic displays. This technological (r)evolution has allowed symbol communication aids to become more usable and prevalent however aspects of the underlying language and communication structure of the devices have remained constant throughout this period. Whilst more recently many symbol vocabulary packages have been developed, some of the key symbol packages developed in the 1970s are still in use.

Each of the components of a communication aid can be associated with attributes – for example the device may determine the physical size or weight, the software may determine the ways in which an individual may access the device, and the vocabulary package may determine the parts of speech which may be understood or spoken using the device.

The physical and software attributes of a communication aid are relatively well investigated, for example O'Keefe et al. [3] and Judge & Townend [4] present a range of physical attributes that are seen as important to those using communication aids such as size, weight, robustness and voice output. Attributes of vocabulary packages discussed in the literature focus on the arrangement (layout) of the symbols or words and the language organisation scheme within a system, for example as described in Drager et al. [5].

Symbol communication aids are often provided following an assessment process which will either explicitly or implicitly consider attributes of the communication aid. Assessment and decision making about the most appropriate symbol communication aid for a child is complex, challenging and little understood [6, 7]. It is not clear how attributes of the communication aid are related, how they are considered, and how different characteristics of a child might influence the decision to choose a specific communication aid or attribute [8, 9]. Webb et al. [10] investigated the decision making process using a stated preference experiment with AAC professionals and found that communication, language, and interface-related attributes were generally considered as more important than hardware and physical attributes. This highlights a potential dichotomy between the literature and practice and a need for a greater understanding of the language and communication attributes of symbol communication aids.

The impact of the choice of a symbol communication aid is likely to be significant and this is particularly pertinent when considering a child as the impact may be life-long. Despite the importance of these decisions Johnson et al. [11] note significant variation in provision and unacceptably high levels of abandonment of communication aids of between 30-50%.

The work presented in this paper is part of the wider I-ASC research project (http://www.i-asc.org.uk/). The main aim of the I-ASC project is to improve decisions about the choice of symbol communication aids and their appropriateness for individual children and to ultimately improve the outcomes for children using symbol communication aids. The project involves a range of contributory stages including literature reviews, qualitative interviews and quantitative stated preference experiments. The main output of the project will be to produce a heuristic resource to support the symbol communication aid decision making process.

A number of conceptual models have been developed to describe the use of Assistive Technology and communication aids [4, 12, 13]. These models can broadly be described as sharing components that relate to the individual using the communication aid, their context, the environment, the communication partners around the individual, and the communication aid itself. All aspects of these models are reflected in the wider I-ASC project work however this review focusses specifically on the language and communication attributes of the communication aid itself.

This systematic review was designed to inform the outputs of the I-ASC project. The review had two specific aims:

(1) To identify from the literature the language or communication attributes of graphic symbol communication aids that currently influence clinical practice.
(2) To inform the development of attribute lists required for two stated preference experiments on graphic symbol AAC decision making (reported elsewhere).

Methods

The research question for this review was defined based on the study aims: in considering the AAC literature on device attributes, what evidence exists to inform clinical decision making in relation to the language or communication attributes of graphic symbol based communication aids?

Identification of Studies

A review protocol was drawn up using the PRIMA-P [14] template and a search strategy was developed based on the research question. The search string (summarised in Table 1) incorporated search terms that were synonymous to the terms symbol communication aid and attribute.

Searches, using the search strategy, were performed on the EBSCO, EMBASE, PROQUEST, Scopus, Web of Knowledge, Cochrane Library and AAC journal electronic databases. When possible searches were refined by excluding categories that could not be related to AAC (e.g., animal studies). The second author executed the database searches.

INSERT TABLE 1 HERE

Inclusion and Exclusion Criteria

The selection criteria for papers is shown in

Table 2. The intervention of interest was the use of symbol communication aids – these were defined as those where the main method of language representation was through the use of graphic symbols. This did not preclude systems where a text gloss was also presented under the symbol, but did exclude symbols were graphic symbols were not used

in the language representation (e.g. only as icons for functions such as save). Only papers reporting studies where communication aids were used expressively were included –in other words when they were used to convey meaning. This did not exclude paper based systems, but would for example exclude the use of graphic symbols to aid language comprehension.

Any study design was accepted, i.e. empirical research involving participants being subjected to an intervention. As an example, discussion papers, opinion papers, narrative reviews were not included.

A number of decisions were made in an attempt to ensure that all relevant papers were included given the anticipated scarcity of literature:

- Papers reporting studies involving a mix of participants were included when more than 20% of participants involved met the inclusion criteria.

  Papers reporting studies where the diagnosis of participants was not reported were included when it was reported that participants' speech was insufficient for daily needs.
- Studies involving either child and/or adult participants were included. Although the focus of the wider I-ASC project is on decisions about communication aids for children this study focused on attributes of the communication aid itself and so studies involving adults or a mix of participants may provide results that could inform these decisions.
- A cut off of 1970 was selected. Both paper and screen based communication aids may contain language and communication attributes and so papers describing earlier systems may still provide relevant results.

INSERT TABLE 2 HERE

Selection of Studies

The resulting citations were downloaded to a local database and managed using the JabRef software tool (http://www.jabref.org/). Due to the volume of papers, the initial review process was carried out in two stages. An initial title and abstract review stage excluded articles not related to AAC was carried out by the second author. The first and second author then independently carried out a title and abstract review of the remaining literature for relevance to the research question. Any paper marked by either author as meeting the inclusion/exclusion criteria was retained for full paper review.

Finally the full text of the remaining papers was reviewed by both first and second authors independently. Papers included by both researchers were included in the review. Papers included by only one researcher were discussed until a consensus opinion was agreed with the third author arbitrating if needed.

Quality Appraisal

The Crowe Critical Appraisal Tool (CCAT) [15] was used as a basis for quality appraisal. CCAT was used as unlike other tools considered CCAT supports the inclusion of a variety of study designs. CCAT was also chosen as it allowed the outcome of the appraisal to be used as a criterion for acceptability and prior to the review, a score of less than 40% on the CCAT tool was agreed as weak.

Quality appraisal was carried out by the first and second author independently. Papers rated as weak by both authors were excluded from the review. Papers rated as weak

by only one researcher were discussed until a consensus opinion was agreed with the third author arbitrating if needed.

Analysis and Interpretation

A data extraction table was designed by the first and second authors to address the research question and aims. The data extraction was piloted and refined using a small number of papers: data from the included papers were extracted by the first author and the extraction reviewed by the second and third authors. Data extracted were study design, participant sample size and characteristics, existing graphic symbol system(s) used by participants, language or communication attribute studied, research question, intervention, measures, and results.

There is known to be a lack of controlled trials within the AAC field and thus a thematic meta analysis or textual narrative synthesis approach to analysis and synthesis was planned[16, 17]. The extracted data of each paper were reviewed and papers were jointly grouped into themes relevant to the research question by the first and second author with the grouping reviewed by the third author. Each thematically grouped set of papers was then reviewed by both first and second author to establish any possible meta analysis or synthesis of the findings.

Results

The initial database search, detailed in Table 3, identified 54,673 papers.

INSERT TABLE 3 HERE

Papers were screened as described above and this is represented in the PRISMA flow chart in Figure 2.

INSERT FIGURE 2 HERE

489 papers of the 503 full papers were excluded following full text review. Papers excluded at this stage included: those studies reporting attributes of symbols such as iconicity but where these were not used in an expressive communication aid; studies involving typically developing children without language or communication difficulties; studies investigating the effect of implementation strategies, rather than the effect of a communication aid attribute; studies investigating the effect of AAC use by an individual (i.e. their skills in use), rather than the effect of the aid attribute; studies describing but not evaluating the development of communication aid innovations; studies comparing the effect of different modes of communication; studies looking at attitudes or perceptions of others' to communication aid use; studies investigating speech synthesis intelligibility; and reviews and best practice articles discussing clinical practice around decision making.

Participant and Study Characteristics

Following the screening process 11 papers were identified and data extraction was completed, summarised in Table 4. The included studies reported data from 66 relevant participants (assuming no overlap of participants) of whom 88% were reported as having Cerebral Palsy, 58% were reported to be children or young people and 58% were reported to be male.

Eight of the studies, involving 73% of participants, took place in North America (6 USA, 2 Canada) with the remaining three studies being carried out in the United Kingdom, Australia and South Africa. Five of the papers were published prior to 2000 and nine prior to 2005.

Seven of the papers could be described as single case (within-subject) experimental or quasi-experimental design using the typology proposed by Tate et al. [18] the remaining papers consisted of 2 surveys and 2 case studies.

Themes

Thematic analysis of the included papers resulted in three main themes of vocabulary organisation and design, symbol system and encoding, and vocabulary selection. A supplementary theme of innovative attribute development was also included.

The included papers had very diverse research aims and outcomes and this heterogeneity meant that no meta analysis within or across themes was possible, nor was any synthesis of conclusions across the studies in each theme.

The included papers are presented in Table 4 and presented below, organised by theme, and with a summary narrative provided. Relevant findings from the quality appraisal are included in the description where potential risk of bias or challenges to the study validity were identified.

Theme 1: Vocabulary Organisation and Design

Three papers reported data from studies related to vocabulary organisation and design. All three studies involved participants trialling communication aids with different combinations of what were described as static versus dynamic organisational schemas. Varying

terminology was used to describe the different vocabulary organisational schema used within these studies:

- A set of graphic symbols arranged in a matrix on a single page that did not vary was referred to as "single-level" by Hochstein et al. [19], the same arrangement was referred to as a "fixed display" by Reichle et al. [20].
- A set of graphic symbols arranged in a grid matrix on a single page that did not vary and where each symbol was associated with more than one vocabulary item was referred to as a "static scheme" by Hochstein et al [21]. In this study two modifier keys were used to switch between outputting the noun and verb form of each symbol displayed.
- A set of graphic symbols arranged in a grid matrix on more than one page, where each symbol represented a single vocabulary item and where pages were navigated to using category (page) keys was referred to as "dual-level" by Hochstein et al [19] and as "dynamic" by Hochstein et al. in a later paper [21].
- Reichle et al. [20] also described two presentation schemas termed "dynamic passive" and "dynamic active". In these schemas a set of graphic symbols were arranged in a grid matrix on two pages, with each symbol representing a single vocabulary item. In the "passive" presentation the participant had to press a single (non category based) "next page" key to get to the second page. In the "dynamic active" presentation the subsequent page was automatically navigated to every time a vocabulary item was selected.

Hochstein et al. carried out two studies – both quasi-experimental mixed factorial study designs with eight participants with complex communication needs. The primary aim

of the first study [19] was to investigate the nomothetic approach, however the study had a secondary aim of examining the effect of what was termed display levels and vocabulary concreteness on the use of a communication aid. The study compared between organisation schemas described as single level or dual level with a small number of symbols in a task not representative of expressive communication where the participant was asked to match the symbol to a word spoken to them by the experimenter. In this study the single level display produced less errors and concrete items were found to be easier to recall by participants than abstract ones. The second study [21] was of similar design and in this study the organisation schema described as static promoted higher rates of vocabulary recognition during initial learning but was replaced by an advantage of the dynamic organisation scheme after training (the 7th and 8th trials in the study).

Reichle et al. [20] alternated organisational schemas between schemas they termed fixed, dynamic passive and dynamic active. The study involved a symbol to photograph matching task with a small (30 symbol) symbol set with a single participant described as having “severe mental retardation”. For this participant there was not a significant difference between dynamic active and fixed organisations tested in terms of speed or accuracy of symbol selection.

The quality appraisal process identified two potential challenges to the validity of this result when considering it in the context of the communicative use of symbol communication aids. Firstly it is not clear that the symbol to photograph matching task used would transfer to unprompted use in communicative environments. Secondly the method does not adequately explain the results for the “dynamic active” condition. The method states that page changing occurs every time a symbol is pressed on the communication screen and each screen only displays half of the available symbols, this would suggest that

for a randomly presented photograph the matched symbol would not be present on the communication screen for around half of all responses. The reported accuracy results are all greater than 60% (rising to over 90%) and so it appears the photograph was chosen by the experimenter to correspond to the current screen or that the method or condition is not fully described.

Theme 2: Symbol System & Encoding

Three papers reported data from studies related either to the symbol system or encoding methods used within symbol communication aids.

The study reported by Hurlbut et al. [22] had the aim of establishing which of two symbol systems is more easily acquired and maintained when an individual is trained on its use with nouns. Blissymbolics, a predominately ideographic symbol system [23], was compared to line drawn iconic pictures drawn with the intention of showing a high degree of similarity with the object they represent. Twenty of each of the symbols were then placed on a single page communication board and provided to three males with Cerebral Palsy as part of a within-subjects study. Stimulus generalization was evident in both symbol systems however higher scores were reported for iconic pictures. Although students made both types of responses during daily activities, the use of iconic pictures was more extensive in spontaneous use.

A number of factors were identified in quality appraisal as limiting the interpretation of these results. Participants were all described as having “severe retardation” however the inclusion/exclusion criteria are not listed and it was reported that teachers felt that participants’ receptive language was above that reported in the test results. The test used to assess receptive and expressive language is not validated for this age group or level

of physical disability and it is not made clear if the assessment was carried out by the researchers or taken from records. Secondly, the choice of items for the intervention was based on items that were readily visible in the environment – which limited the symbol vocabulary to nouns. Thirdly, in the spontaneous use task, both types of symbol were included on the communication board which is unlikely to be representative of use in a naturalistic communication task. Finally, no description of the analysis or statistical methods is provided.

Light et al. report two studies investigating the process of using short codes to create longer messages, termed "message encoding" [24, 25]. Both studies compared letter codes based on the first letters of salient words in the message (e.g CE would expand to "can I have something to eat"), letter category codes based on the first letters of a category plus a specifier (e.g., RE to stand for a Requests to do with Eating), and iconic codes derived from the icons and semantic associations proposed by [26] i.e. Minspeak™ (e.g., the icon of an apple followed by a question mark to stand for food and requests).

The first study found that the salient letter technique had significantly higher recall than the letter code or iconic techniques. In both studies concrete messages were also found to have significantly higher recall than abstract ones. There was no interaction effect between these two factors. The accuracy of the code recall increased for all learning and testing sessions (for all techniques) in both studies. In the second study no benefit was found for use of personalised codes over non-personalised ones.

The quality appraisal identified that the participant cohort in the first study was biased towards functionally literate individuals and those with Cerebral Palsy. The authors note this and attempt to address this in the second study however in this study the participants included were all above grade 1 (age 6-7) in reading ability and all but one had

Cerebral Palsy. In both studies, the sample also excluded those already familiar with Minspeak™ (the underlying language representation system of one of the techniques evaluated) but did not exclude those familiar with orthography (the underlying language representation system of two of the techniques evaluated). Light et al. also highlight that this is a study of immediate recall and that the implications for long term recall and use are not clear.

Theme 3: Vocabulary Selection

Three papers investigated the process of selection of the symbol vocabulary to use on a communication aid.

Bornman & Bryen [27] aimed to investigate the social validity of a specific vocabulary set used on communication boards by determining the importance of these vocabulary items to 12 adults who use AAC. The results suggest participants concurred with most (80%) of the vocabulary selected by a variety of knowledgeable informants.

Bornman and Bryen identified that the study had a small response rate and participants were recruited as an purposive sample which may have provided skewed data. There were also no test-retest or internal consistency reliability measures of the data collection tool.

Yorkston et al. carried out two studies looking at vocabulary selection. The first study [28] involved nine participants who contributed their vocabulary lists which were then compared with each other and then against standard vocabulary lists. The second study [29] presents a case description of the process of vocabulary selection and a comparison of the selected vocabulary against standard vocabulary lists. Inspection of participants' vocabulary lists highlighted that these were small vocabularies compared to estimates of

common English words or standard vocabulary lists. Minimal overlap between any two vocabulary lists was found. Comparing against the standard lists showed that the larger vocabulary lists contained a greater proportion of users' vocabularies, but no standard vocabulary list contained all words included in even relatively small user vocabularies.

Theme 4: Innovative Attribute Development

Two papers reported studies carried out as part of the development of an innovative communication aid attribute – i.e. attributes that are not currently available in commercial systems.

Black et al. [30] studied the use of the "How was School today. . . ?" research software developed by the team. This software generated utterances to support narrative story telling based on data from sensors relating to where the participant had gone in school, who they had interacted with and information from the school time table. The participants then used symbols to choose to speak one of a range of possible utterances prepared by the software, for example "After break I went to the Hall during Work World. Great! I had Mrs Kerr instead of Mrs Moore. Katie was there. She is nice."

Black et al. evaluated this system with two formative evaluations as part of a user centred design method by adding the research software to the communication aids of three children with cerebral palsy. The system was used with two participants in the first evaluation and was used successfully to generate stories. Black et al. reported that the system worked better for a child with major motor impairment but reasonable cognitive skills, than for a child with better motor skills but more intellectual impairment. Black et al also reported that during the second evaluation it became clear that the system was still far

from being able to be used independently without intensive technical and pragmatic support or training.

Stewart & Wilcock [31] studied two methods of novel symbol vocabulary prediction. Participants used a single page 6x6 symbol vocabulary grid matrix displayed on specific research software and setup with vocabulary items related to the specific story book used in the task. Stuart & Wilcock carried out a single case experimental ABACA design study studying two prediction conditions: regular prediction where predicted symbols were presented in a list external to the symbol matrix, and internal prediction where predicted symbols were presented at their place in the matrix. Three participants with cerebral palsy used a switch to copy sentences from a story book using the software in 20 minute sessions daily until all 26 sentences were complete. Visual inspection of the results suggested that the prediction programs were the fastest in all three cases but that fewer errors were present in the no-prediction condition.

The applicability of the findings beyond the task and specific software used within the study is not clear. Stewart & Wilcock note that the copy task is not representative of the use of such a system in conversation, in addition given that the prediction software used had high level of prediction certainty and the vocabulary used was very small it is clear that there is potential for a learning effect. It is not clear how participants were recruited and participants' language and communication skills are not well described.

Discussion

The primary aim of this systematic review was to establish the evidence that exists to inform clinical decision making relating to graphic symbol based communication aids for children. This review demonstrates that there is little research evidence on which

practitioners can be basing their decision making about what specific symbol communication aid to choose. Readers looking for information to directly inform their clinical practice are unlikely to be able to draw significant conclusions from the literature.

The secondary aim of this work was to identify characteristics of symbol communication aids prevalent in the literature in order to support the development of two stated choice experiments. A small number of attributes emerged from this review of the research literature and thus the development of the attributes required in the stated preference experiments drew more strongly on qualitative data gathered as part of the I-ASC project from AAC practitioners, service users and family members.

This work suggests that there is not a strong conceptualisation of symbol communication aids within the research community and attributes that have been studied are inconsistently defined. If clinical practice reflects the literature, it is possible that the concept of communication aids having language and communication attributes is not strongly ingrained. It may be that communication aids are not viewed as a conglomeration of attributes from which to choose but as a completed product. This review identifies an urgent need for further work to better describe and understand the impact of the attributes which make up graphic symbol communication aids.

This finding contrasts against an associated literature review carried out by the authors looking at the characteristics of children considered in the same decisions and which established a much stronger literature. This variation suggests that AAC researchers may assign more value to studying the aspects of these decisions related to the child rather than anything perceived as technological. Other authors such as Light & McNaughton [32] have argued about the potential for technology obsession when considering communication aids and that practitioners must “ensure that AAC intervention is driven, not by the devices,

but rather by the communication needs of the individual" (p299). Whilst this is undeniably true it is suggested that better understanding and consideration of the language and communication attributes of communication aids will lead to better outcomes for those using AAC.

This review also suggests a number of questions related to how the symbol vocabulary packages used in practice are developed and constructed. Symbol vocabulary packages available commercially will frequently include claims in marketing literature describing them as evidence based: this study has not identified empirical evidence from studies of participants who use AAC to support these claims. Further, the literature included in this study does not provide any significant 'blue-print' for AAC system developers to inform their design and so we should also ask the question 'what does inform the design of these packages'?

What was noticeably absent from this review were any studies involving the vocabulary packages that we observe as currently being used in practice. No studies were included that studied commercially available vocabulary packages or specific attributes of them. The attribute of vocabulary organisation is often discussed in practice and some tentative conclusions could be drawn from our review about the use of different organisation methods with a small number of symbols. It is suggested however that the description and presentation of the systems evaluated in the included studies would not be recognised by most practitioners.

Overall the strength of the evidence reported in this review can be considered to be weak. No meta analysis or synthesis of results from the included papers was possible. The predominate method used in studies was single case pseudo experimental design and only one study included a control and could thus be described as single case experimental

design. The majority of studies relied on a study design that utilised artificial tasks such as a symbol to photo matching or copy typing rather than studying use within a natural communicative environment. All studies evaluated communication aids with a relatively small number of symbols - typically around 30 symbols over one or two pages. It is unlikely that performance with these tasks with these communication aids will generalise to communicative situations. Where data were gathered in communicative situations there were other challenges to the external validity of the design. The cohort of participants recruited to the included studies is not representative of the AAC cohort with developmental conditions and the skills and abilities and demography of the participants was in general poorly described.

In part the poor strength of evidence may reflect the overall challenge, both practical and ethical, of carrying out robust studies with this population and in particular in designing robust experiments to investigate a specific attribute of a symbol communication aid. This challenge may in part be why more recent studies have used a nomothetic approach, as described by Hochstein et al. [33], of studying participants who do not use AAC. It is clear that further work is required to develop and evaluate appropriate research designs to study attributes of communication aids with cohorts of individuals who use AAC.

Limitations

The quantity of papers included in the early stages of this review should be noted: this reflects the dual or generic meaning of some of the search terms in our search and also the challenge of terminology within the field of AAC. A large number of papers were also included at full text review: much of this reflects the discussion in papers of the potential

implications of a study on clinical decision making. Such a large search pool is a potential limitation as this could lead to human error in the review process. To mitigate this risk, a two stage title and abstract review was implemented and two researchers independently completed both the second stage of title and abstract review and the full text review.

As discussed the strength of the literature included can be described as weak and a number of methodological challenges are identified in the included papers. This may suggest that the 40% inclusion threshold chosen with the CCAT tool may have been too low and future studies may consider a different threshold.

Conclusions

There are few studies that investigate the language or communication attributes of symbol communication aids that clinicians or others can use to inform their decision making regarding the selection of a communication aid for a child.

This systematic review identified some studies that investigated a small range of attributes which were classified as vocabulary organisation and design, vocabulary selection, and symbol system and encoding. The strength and depth of the literature included was considered weak and issues were found with most papers which would effect their validity or interpretation when applied to communicative situations in practice.

No studies were found which studied attributes of vocabulary packages which are currently observed in use. The terminology used within the literature varies and is poorly defined.

Overall this review highlights the need for further studies to be carried out which use robust research designs to investigate the effect of specific language or communication attributes of communication aids.

INSERT TABLE 4 AT THE END OF THE PAPER

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Disclosure of interest.

The authors report no conflict of interest.

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Tables

Table 1. Search string used in study

(Symbol* OR (aided AND (communicat* OR language)) OR (Graphic AND Representation*) OR "Alternative Communication" OR "Augmentative Communication" OR "Augmentative and Alternative" OR "Alternative and Augmentative" OR AAC OR (Assistive AND Technolog*) OR (Complex Communication Need*))
AND
(attribute* OR feature* OR quality OR qualities OR characteristic* OR design* OR specification* OR (vocabulary AND (organisation OR organization)))

Table 2. *Study selection Criteria*

Inclusion Criteria	Exclusion Criteria
Population	
Developmental disabilities	Acquired conditions
Speech that is insufficient for daily needs	Verbal participants were reported to be at a pre-symbolic level
Intervention	
Graphic symbol (non literacy) based AAC systems	Non expressive AAC systems
Outcome	
Outcomes related to a language or communication attribute of the system	
Design	
Any study type	Non studies
Publication Type	
Any published paper since 1970	
Any language	

Table 3. Results of database searches and initial title review

	Initial Search Minus Duplicates (for each search)	AAC Related	AAC Related Minus Duplicates (combined)
AAC Journal	867	867	
Cochrane Library	0	0	
EBSCO	6,872	380	
EMBASE	406	37	
PROQUEST	10,219	84	
Scopus	15,786	659	
WoK	22,742	629	
TOTAL	56,893	2,656	1,899

Table 4. Summary of included studies (data extraction table)

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Theme 1: Vocabulary Organisation and Design				
Hochstein et al, 2003	Quasi-experimental: 2x2x2 mixed factorial Only 2x2 relevant to this review	8 participants diagnosed with CP: Vocabulary age equivalency 3;3-8;1. Unfamiliar with either presentation system Severely speech impaired Able to use direct selection. Hearing and vision WNL 8 children without disabilities matched to vocabulary age equivalences.	Not specifically detailed. "All participants selected had to have a lack of familiarity with both of the two presentation systems" "The speech impaired children who had familiarity with AAC systems were only allowed to have familiarity with noncomputerised systems or level static systems in which the levels had to be manually placed."	Display levels & vocabulary abstractness. Number of display levels: single / dual Vocabulary abstractness: concrete / abstract.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Hochstein et al, 2004	Quasi-experimental 2x2x2 mixed factorial Only 2x2 relevant to our review	Two groups of 8 (16 in total): CCN and speech skills CCN group: CP 4;0 – 19;11y. Unfamiliar with either presentation system. Severely speech impaired. Able to use direct selection. Hearing and vision WNL	CCN Group: Sign (1) Manual communication Board (1) Sign and Manual communication Board (2) Macaw (2 years) (2) Prior trial of 2 devices (1) Not available (1) Speech Skills Group: None.	Presentation scheme –static or dynamic. Static Display = Icons fixed on device in a matrix. All available icons visible at all times. For sufficient vocabulary set, each icon associated with two or more vocabulary items. In this study icon represents either noun or verb (changed with two modifier keys). Dynamic (or Hierarchical) Display = Only portions of available icons visible at any one time. Available icon display dependent on category selected by operator
Reichle et al, 2000	Within subject, Alternating Treatment, repeated measures.	"Sarah" – 16 years old, severe mental retardation, receptive language score in first percentile on formal assessment. Approximately equal exposure to each display strategy prior to the study.	Macintosh PowerBook 540C with Speaking Dynamically™ v1.2 software. Approximately 10 pages with 10 to 30 symbols on each page. Combination of colour and black and white line drawings produced with Boardmaker™ and PCS . Proficient, using device for several years. Used both types of dynamic display systems tested – roughly equal exposure.	Arrangement/layout of symbols Fixed Display - All available symbols in an individual's repertoire displayed on one page. Dynamic Passive Display: All symbols displayed across two pages. To change pages explicit "navigation buttons" must be used. 3. Dynamic Active Display: All symbols displayed across two pages. Every symbol press changes the page to the next page.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Theme 2: Symbol System & Encoding				
Hurlbut et al, 1982	Quasi Experimental. Authors describe as "Within subject: Multi-element baseline"	3 males with quadriplegic CP (range of type and severity). 14-18y. Personal social skills: 14 – 16.5mo Fine motor skills: 7.5mo Expressive Lang: 10mo Receptive Lang: 2.5 – 13.5mo All reported to exhibit receptive language beyond that suggested by formal assessment. Able to follow instructions similar to those used during experiment and identify stimuli used as basis for training.	Expressive language limited to yes/no responses, idiosyncratic gestures, 1-3 Bliss symbols All students received training in use of Blissymbolics for approximately one year, using communication boards "similar to traditional models".	Graphic symbol system – Blissymbolics vs iconic pictures. Blissymbolics: Concepts represented by combinations of geometric shapes. Some symbols visually resemble objects they represent. However, symbols more often represent abstract concepts than concrete objects. Iconic pictures: Described as "colored line drawings". Simple, iconic line drawings that generally show a high degree of similarity to the objects they represent.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Light et al, 1990	Within subjects, repeated measures	6 physically disabled adults with functional literacy: 5 CP, 1 DMD. 21-31y. 5F, 1M. non-ambulatory; speech inadequate to meet daily communication needs; use of AAC system(s) not involving any of the message encoding techniques under study; able to use direct selection; hearing and vision WNL. Functionally literate, but range of experience with traditional orthography. Educational history and achievement levels vary.	Used communication aid for at least a year prior to study. 1. Alphabet & word board; Touch talker with Minspeak software 2. Speech; Alphabet board 3. Speech pac / Epson 4. Alphabet board 5. Alphabet & word board 6. Speech; Alphabet & word board Subjects 1,3 and 6 former Blissymbolics users.	Message encoding with iconic codes: 2 element coded access to whole utterances. Letter codes based on the first letters of salient words in the message Letter category codes based on the first letters of a category plus a specifier Iconic codes derived from the icons and semantic associations proposed by Baker - ie Minspeak.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Light1992	Within subjects, repeated measures	12 adult participants, congenital disabilities: speech impairment; reading skills at least "grade 1 level". 11 CP, 1 other. 18-35 y	Wide Range, including: 9 spelling or word based system. 3 blisssymbol boards. All for 1 year minimum prior. None used encoding techniques.	Message encoding with iconic codes: 2 element coded access to whole utterances. Letter codes based on the first letters of salient words in the message Letter category codes based on the first letters of a category plus a specifier Iconic codes derived from the icons and semantic associations proposed by Baker ie Minspeak.
Theme 3: Vocabulary Selection				
Bornman and Bryen, 2013	Descriptive survey	12 South African adults with CCN who use AAC. 8M, 4F; 19-39y; 8 CP, 4 acquired conditions; range of educational level, employment status and first language; all literate. 4 indicated had been victims of crime or abuse. Recruited via a week long residential AAC program participants (8) and alumni (4).	Pathfinder Plus (1) Laptops with Grid or E-Triloquist software (9) iPod Touch with Proloquo2Go (1) Lightwriter SL40 and laptop with E-triloquist (1) All participants had access to low tech alphabet boards, but only 2 listed as part of AAC system.	Vocabulary Items: Social validity of a vocabulary selection approach.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Yorkston et al, 1988	Descriptive statistics	9 nonspeaking adult users of AAC systems. 2 F, 6 M; 20-36y; 8 CP, 1 CVA (not applicable to this review); moderate-severe physical handicap; range of spelling skills (< 2nd grade – 6th grade). essentially normal intellectual ability.	Of participants with CP: ACS4 SpeechPac ACS SpeechPac 3x Laptray board Touch Talker + Minspeak Foot-activated rolling display Touch-talker + Express	Standard and user vocabulary lists as a source of vocabulary items for adolescent and adult AAC users.
Yorkston et al, 1989	Case Description Including analysis of vocabulary list produced: % of structure words; and comparison to standard vocab lists.	1 participant - G.T.: 36y, female; CP and spastic quadraparesis; not able to produce intelligible words; no formal education; recognised 5 to 10 sight words, no functional spelling; approx. 11;7 receptive language level skills; motor limitations appeared to be greater obstacle to communication than language skills.	Gross pointing gestures to indicate messages on a board containing 24 messages represented by Blissymbols.	The process of vocabulary selection including methods, content, symbol selection and display.

Theme 4: Innovative Attribute Development

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Black et al, 2012	User Centred Design & Formative Evaluation	3 children with quadriplegic CP. 12;2 – 15;11y; 2 F, 1 M; all use head switch with row – column scanning; 1 & 3 = Little functional speech. 2 = Functional speech but sequencing / memory difficulties. 1 – uses graphic symbols, “emerging literacy”, some whole word reading; 2 – literacy not clear “can copy type”; 3 = Knows about 400 PCS symbols, can type simple sentences using onscreen keyboard.	1. DynaVox DV4. IDV-B. Large vocabulary (words and short messages) stored by SLT. 15 button pages (3 x 5). Graphic symbols for communication. 2. None. 3. DynaVox Vmax. Gateway 40 & on screen keyboard.	Narrative Generation: Generation of utterances to support narrative story telling about school.

Study	Design	Sample size and characteristics	Existing graphic symbol system(s) used	Language or communication attribute studied
Stewart and Wilcock, 2001	Single Case Experimental Design ABACA design across three cases: A = no prediction, B = regular prediction, C = internal prediction.	Three participants. 1. F, 8;4, Athetoid Quadriplegic CP. Reasonably proficient switch user. Functionally non-verbal except verbal "yes" / "no. 2. M, 6;8, Athetoid/Spastic Quadriplegic CP. Just finished switch-training program. Communication mostly facial expression and vocalisation attempts. Access skills considered to be major limiting factor 3. F, 10;2, Athetoid/Spastic Quadriplegic CP. Learning to operate head switch - slow and inaccurate. Often absent due to illness. Communication based on facial gesture and eye pointing.	1. LiberatorTM VOCA. Backup communication board. 2. Learning to use LiberatorTM VOCA accessed with Big RedTM switch. 3. Learning to use LiberatorTM VOCA	Two methods of symbol prediction on single page symbol grid matrix: "Regular prediction" - Predicted symbols presented in a list external to symbol matrix "Internal prediction" - Predicting symbols at their place in the matrix

Abbreviations: CCN = Complex Communication Needs; CP = Cerebral Palsy; DMD = Dystonia Musculorum Deformans ; SLT = Speech and Language Therapist; TBI = Traumatic Brain Injury; WNL = Within Normal Limits; Y=years old (chronological age); F=female; M=Male; PCS = Picture Communication Symbols.; VOCA = Voice Output Communication Aid

Figures

Figure 1. Image of child using a symbol communication aid

Figure 2. PRISMA diagram of review process