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A COMPENSATORY APPROACH TO ACQUIRED DYSGRAPHIA: DEVELOPING SUBLEXICAL SPELLING SKILLS THROUGH A KEYWORD RELAY STRATEGY

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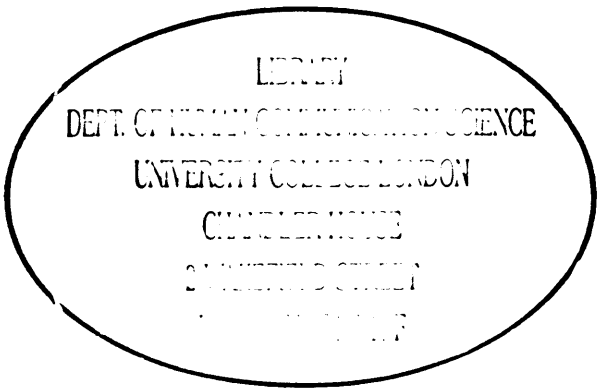

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Abstract

This single case study evaluates the efficacy of therapy for a client, GK, who has acquired dysgraphia. A compensatory therapy approach was taken, aimed at improving GK's sound-to-letter correspondences for word-initial sounds by way of a keyword relay strategy. The strategy was broken down into three stages for each item which was presented: (1) naming a picture and segmenting its initial sound, (2) matching this sound to its corresponding keyword picture, and (3) matching the keyword to its corresponding letter on a keyboard letterboard. Comprehensive pre-therapy investigations were carried out into GK's cognitive and language skills, with a particular focus on his writing abilities. A combination of a multiple baseline and an item-specific therapy design was employed. Quantitative and qualitative information was gathered throughout by recording GK's verbatim responses and observing the strategies which he used to map sounds to letters. Post-therapy assessment results show that this approach was effective in significantly improving GK's sublexical spelling skills and indicate that the strategy had generalised to a variety of items and tasks.

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Introduction

The cognitive neuropsychological approach to dysgraphia

For the past 30 years, the cognitive neuropsychological approach has been commended for its utility and productivity within aphasia therapy (Whitworth, Webster & Howard, 2005). By focussing on the individual components and interconnections involved in the processing of single words, cognitive neuropsychological assessment provides a comprehensive description of the precise nature and extent of the impairment, together with an understanding of which elements remain intact. This guides further investigation and provides the rationale for the selection and subsequent adaptation of particular approaches to intervention, by allowing strengths to be maximised and difficulties to be addressed or avoided. Outcome measures can then be employed to evaluate improvement in therapy-specific items or tasks, identify any generalisation effects, and explain why therapy has or has not been successful. Used within a total communication framework, a cognitive neuropsychological approach can facilitate the provision of individualised, holistic care and enhance the functional communication skills of the patient (Beeson & Rapcsak, 2002; Whitworth et al, 2005).

The production of the written word requires a 'multitude of cognitive, linguistic, and perceptual-motor processes' (Beeson & Hillis, 2001, p583). A cortical lesion, such as a cerebro-vascular accident (CVA), may trigger a deficit to one or more of these processes and result in impaired written communication, either in isolation ('pure dysgraphia') or, more frequently, as part of a wider language impairment.

Acquired dysgraphia has a unique impact on the individual concerned, primarily depending on their pre-morbid writing skill and use, the extent of their dysphasia and its psychosocial consequences. Whilst the majority of therapy tends to focus on spoken language production (Beeson & Rapcsak, 2002; Rapp & Kane, 2002; Whitworth et al, 2005), the relatively few treatment studies concerned with the remediation of written spelling deficits confirm that therapy can improve writing skills and that, for some people, writing may even be more amenable to

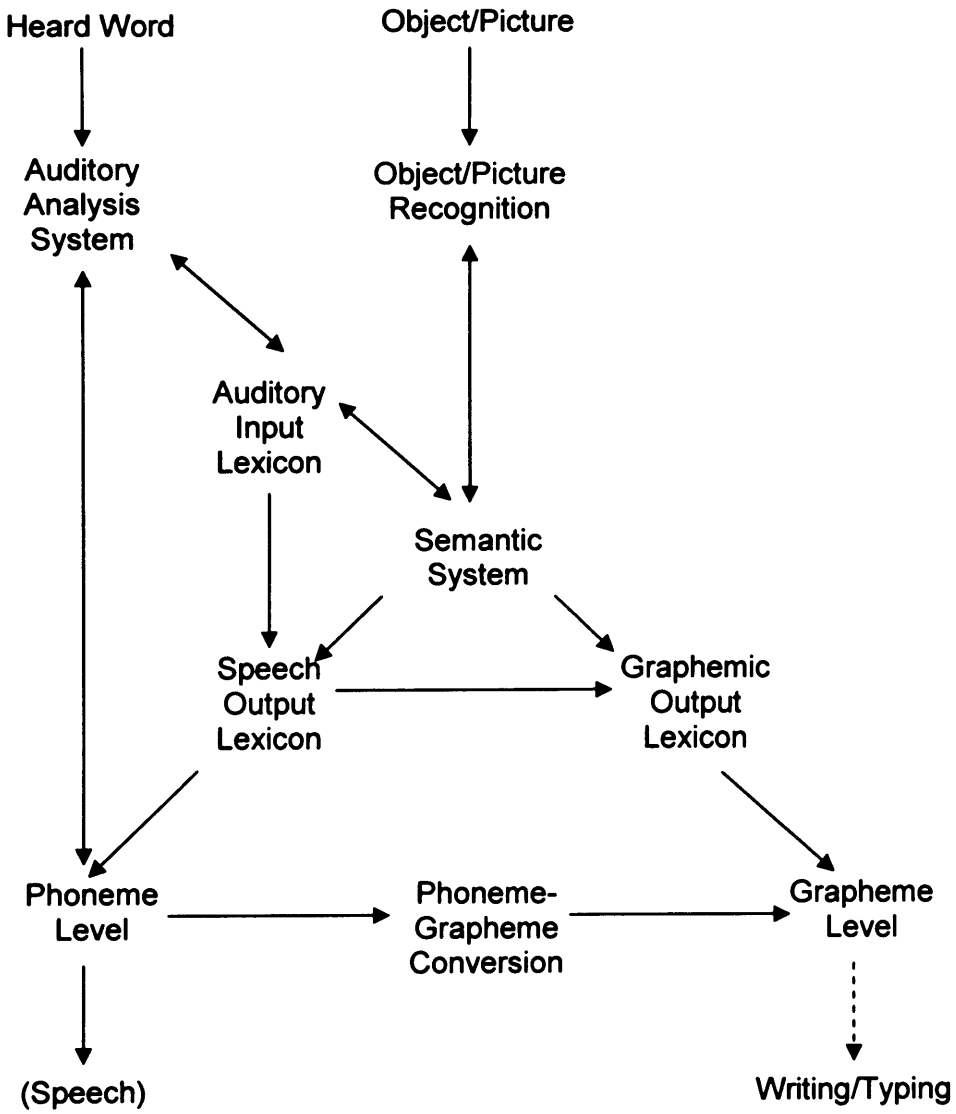
therapy than speech (Beeson 1999; Hillis Trupe 1986). Moreover, focusing on improving written spelling skills has also been shown to facilitate the production of the spoken word (de Partz, 1986; Nickels, 1992).

Model for the written production of single words (spelling)

The relationships between the processes which support spelling and writing (namely writing words to dictation, written naming and spontaneous writing) are depicted in Figure 1.

Figure 1

The dual-route model of written production of single words (spelling), based on Ellis and Young (1988)



This model will be explained in terms of writing to dictation. Once the stimulus has activated the auditory analysis system, either one of two lexical routes or a sublexical route can be taken (Ellis, 1996; Whitworth et al, 2005):

Lexical route

This route is used by skilled writers to spell a regular or irregular, familiar real word, since its auditory representation is stored in the individual's input lexicon and its spelling is comprised as a whole string in the graphemic output lexicon. The graphemic output lexicon is activated either via the semantic system or directly. The lexical-semantic route is the usual spelling mechanism since it is based on the association between word meanings and graphemic word forms. It is therefore necessary for spontaneous written communication, written naming, and the spelling of homophones. The semantic system activates the graphemic output lexicon with or without additional input from the speech output lexicon. However, the direct lexical route enables the writing of a word without semantic knowledge, and activates the graphemic output lexicon after retrieving the word's phonology from the spoken output lexicon.

> I spell *relief* easily, each letter flows into the next. Most words are like that – *mother, door, bed.* I just know how to spell them. (Beeson, Rewega, Vail & Rapcsak, 2000, p557)

Sublexical route

The sublexical route is used to spell an unfamiliar real word or a nonword, and therefore bypasses the lexicons. It is also heavily relied upon by children and unskilled writers. Here, the heard word is broken down into its component phonemes and these are converted into their corresponding graphemes; the graphemes are then assembled to create a whole word. The assembled spelling thus reflects regular spelling rules, and results in the 'phonetic misspelling' of an irregular word. The sublexical route can provide an important compensatory spelling strategy when the lexical route is impaired. This will be investigated further below.

> Sometimes I write phonetically – *expearens >experience...* Sometimes it backfires. I have the word *agst* (with *g* – like *giraffe*). It takes a while to discover it should be *adjust* – so it's not *g* – like *giraffe,* but *J* – like *Jupiter.* (Beeson et al, 2000, p557)

Whichever route is used to access the spelling of a word, as an individual prepares to write a word and as a word is written it is held in short-term storage as a series of abstract letter representations in the graphemic buffer. This allows implementation of spelling in several forms such as handwriting or typing. Written spelling requires the implementation of further peripheral processes whereby the specific letter forms, allographs, are selected and graphic motor movements are planned and executed (Beeson & Hillis, 2001). Since this paper focuses on central acquired dysgraphia, no further reference will be made to the peripheral spelling process.

Deficits in written spelling

Since any of the modules or connections can be lost or damaged, a wide range of possible patterns of performance may result from a cortical lesion, depending on the location of the impairment and whether alternative processes remain available for use. Whilst individuals often present with somewhat ambiguous and complex error patterns, the dual-route model allows for classification according to which route is primarily damaged, and the resulting syndrome is described in terms of 'deep', 'phonological' or 'surface' dysgraphia (Beeson & Hillis, 2001; Rapp & Kane, 2002; Whitworth et al, 2005).

Deep dysgraphia results from writing via an impaired lexical-semantic route, with an additional deficit in phoneme-to-grapheme conversion. This is typically characterised by semantic errors, and effects of imageability, grammatical class and lexicality (Beeson et al, 2000; Hillis Trupe, 1986).

Phonological dysgraphia is observed when isolated damage to the sublexical spelling route causes spelling to be accomplished exclusively by the lexical-semantic route. This is manifested in the poor spelling of nonwords and unfamiliar words, and therefore is of relatively little consequence in the presence of a well-functioning lexical-semantic spelling route (Hillis & Caramazza, 1994).

Surface dysgraphia is the result of reliance on the sublexical phoneme-to-grapheme conversion process due to a damaged graphemic output lexicon. This is exemplified by a regularity effect, regularisation errors, errors involving

partial knowledge of irregular words, homophone spelling confusion and a frequency effect (Beeson, 1999; Rapp & Kane, 2002).

Approaches to therapy for acquired dysgraphia

Various therapy approaches to acquired dysgraphia have been taken. Therapy for the lexical route has employed reactivation techniques and relay strategies in order to strengthen the graphemic output lexicon. Reactivation involves training clients to write whole words through repetitive practice, for example using anagram and copy treatments or copy and recall treatments (Beeson, 1999; Rapp & Kane, 2002). Lexical relay strategies comprise linking words which are difficult to spell with words which can be reliably spelled (Hatfield, 1983), linking irregularly spelt words with a picture (Behrmann, 1987), and using oral spelling to facilitate written spelling (Mortley, Enderby & Petheram, 2001). Therapy for the sublexical route has involved developing sound-to-letter correspondences, either through relearning or through compensatory strategies (Hillis & Caramazza, 1994), and training a problem-solving approach in which clients are encouraged to self-correct by evaluating assembled words against their whole word knowledge (Beeson et al, 2000); irregular spellings are then promoted through the teaching of specific rules.

Whilst lexical spelling therapies generally result in item-specific effects, generalisation to untreated words is uncommon. In terms of sublexical therapies, there is little evidence for the efficacy of relearning sound-to-letter correspondences; however, compensatory strategy approaches, in which a new means of encoding words is developed by maximising retained skills, are more likely to lead to generalisation of therapy effects (Whitworth et al, 2005). Several studies have been reported in which therapy using a compensatory keyword relay strategy has been shown to improve lexical and/or sublexical spelling skills, with varying patterns of generalisation.

One of the first studies of this kind was carried out by Hatfield (1983) and targeted access to the graphemic output lexicon. Clients with deep dysgraphia were encouraged to use retrievable homophonic or pseudo-homophonic content words as a link to relearning the spelling of function words during writing to dictation tasks. For example, retrieval of the word 'inn' was used to relearn the

spelling of the homophone 'in'; 'Ron' was used to retrieve the spelling for 'on'. Therapy proved successful in circumventing retrieval failure for specific function words. The concept of using preserved words as 'relays' to cue the spelling of other words or to map sounds to letters has subsequently been used by other researchers.

Many studies have investigated the effects of using a keyword relay strategy in order to strengthen the sublexical route. Here, a corpus of keywords is created and used to assist the client in strengthening letter-to-sound correspondences for reading or sound-to-letter correspondences for spelling. The client selects and learns one keyword for each letter of the alphabet. These keywords are then used to link initial letters and sounds of words presented in therapy. This approach demands a range of pre-requisite cognitive and linguistic skills. For example, in written naming, picture recognition and semantic systems require activating in order to provide access to and retrieve a reliable phonological representation of a picture name. Phonological processing skills are required to segment the word into its component sounds, categorise each sound into its phoneme category, and map the phoneme to its corresponding grapheme (Beeson & Rapcsak, 2002). Fundamental to this entire process are attention, memory, problem-solving, reasoning and recall skills, and an adequate processing capacity.

Despite the apparent complexity of this compensatory approach, varying degrees of success have been documented in acquired dyslexia studies (Berndt & Mitchum, 1994; de Partz, 1986; Nickels, 1995; Yampolsky & Waters, 2002). A number of acquired dysgraphia studies have also evaluated this approach, and these will be considered in detail below.

Hillis Trupe (1986) recorded the case of JS, who had severe oral-verbal dyspraxia and severe aphasia, characterised by limited verbal output, little ability to convert phonemes to graphemes and a reliance on single word level written communication with semantic errors. In order to improve JS's single word spelling skills and reduce her semantic errors, a treatment hierarchy was implemented to re-establish 30 sound-to-letter correspondences, using identified keywords which could be reliably spelled as a relay. As JS's phoneme-to-grapheme conversion skills developed, she began to self-cue spellings using their initial sounds and thus block semantic errors. This resulted in more reliable

spelling of regular words, and more plausible spelling of irregular words. JS was then able to type her spellings into a portable text-to-speech system which converted them into synthesised speech.

A similar procedure was employed by Hillis and Caramazza (1994). Their client, SJD, had an impaired graphemic output lexicon specific to verbs and limited phoneme-to-grapheme conversion skills, but good access to her speech output lexicon; she also made semantic errors in writing. She was therefore able to say a verb but unable to write it. In order to promote her use of the sublexical spelling route, SJD was trained in 30 initial sound-to-letter correspondences using a keyword which she was able to spell to represent each correspondence, as above. For example, she could recall that /b/ was the initial sound of her keyword *baby* and that *baby* began with the letter *B*. This strategy facilitated SJD to derive the first and sometimes the second letter of problematic verbs, which in turn cued her retrieval of the whole spelling and thus blocked semantic errors. As a result, she displayed an increased use of correct verbs in written narratives.

Clients who write in regular languages such as Italian can benefit greatly from this sublexical approach. The keyword relay strategy was introduced at a syllable level by Carlomagno and Parlato (1989), who used keywords comprised of retained proper nouns as a relay strategy to derive spellings of syllables. For example, the word *Roma* was recalled, written and segmented into its component syllables in order to retrieve the spelling for the syllable *RO*. The client learnt 30 CV syllables in this way. Post-therapy investigation indicated that the keyword relay strategy had generalised to explicit use in spontaneous writing. Research with six unselected clients with dysgraphia by Carlomagno, Iavarone and Colombo (1994) tested their hypothesis that the stimulation of (partially) spared components of the spelling process is critical for obtaining positive therapy effects. In this study, the lexical relay strategy was combined with a visual-semantic approach in order to exploit residual semantic and partial lexical knowledge. The sublexical strategy was used to re-establish the sound-to-letter correspondences of specified consonants and CV syllables. The visual-semantic approach comprised the presentation of pictures as stimuli for tasks such as written copying and serial ordering of letters. A hierarchy of visual and semantic cues were given; these were decreased as correct responses increased. The authors predicted that each treatment programme would give

significant improvement only in those tasks where lexical or sublexical writing strategies could be successfully applied (eg the visual-semantic treatment should not produce significant improvement in nonword writing). This study further endorsed the use of lexical relay therapy: of the six subjects, five showed significantly improved real word and nonword spelling as a result of the lexical relay strategy (two of these subjects, and the remaining subject, showed improved lexical orthography due to the visual-semantic approach). However, it must be noted that improved sublexical conversion skills in a highly transparent language such as Italian are bound to lead to more accurate word spelling than in an irregular language such as English.

More recently, Beeson et al (2000) introduced a keyword strategy for two clients, SV and SW, who had mild anomic aphasia and dysgraphia. Since the clients demonstrated partial lexical knowledge (eg *bo_t* for 'bought') and partial sublexical knowledge (eg *loil* for 'loyal'), therapy aimed at maximising the interaction between the two spelling routes and developing effective problem-solving strategies. A corpus of keywords which each client could reliably spell was used to establish sound-to-letter correspondences. When the client was either unable to retrieve a spelling or attempting to self-correct, they were encouraged to assemble the spelling using their keyword relay strategy. For example, when attempting to retrieve the letter K for the sound /k/, the keyword *Kim* and its corresponding initial letter were recalled. They also employed an electronic speller which accepted plausible misspellings to resolve spelling difficulties when their own self-correction efforts failed. Following repeated practice, the clients showed enhanced self-correction strategies and significantly improved spelling accuracy. SV required occasional use of the keyword relay strategy to retrieve one or two letters which in turn prompted retrieval of the whole spelling from her graphemic output lexicon. In contrast, SW often required information gained from phoneme-to-grapheme conversion to cue the retrieval of spellings from his graphemic output lexicon (eg 'relaxed': *relacs→relask→relaxed*). A critical factor in this outcome, particularly for SW, was the intensity of stimulation which was provided as the clients daily completed their homework. The authors surmised that such intensity may be key for effective spelling rehabilitation.

It has therefore been proven that taking advantage of sublexical processes using a compensatory approach can improve both sublexical and lexical skills.

Clients who have access to phonological representations for words but cannot generate plausible spellings may be aided by using a keyword relay strategy to strengthen sound-to-letter correspondences. This may also improve their ability to self-cue the lexical spelling and to self-correct (Beeson & Hillis, 2001; Beeson & Rapcsak, 2002).

The current study

This paper investigates the efficacy of a treatment for GK who has very limited written output post-stroke. He has impaired lexical and sublexical spelling processes. Due to the severity of his impairment, a compensatory approach to treatment was taken. Since GK has retained some access to the phonological representations of words which he is unable to spell and also has some limited ability to point to letters, therapy focussed on developing his sound-to-letter correspondences for the initial letters of words by way of a keyword relay strategy. The aim was to provide him with skills that would in the future enable him to select the initial letter of a word on a computer keyboard.

Although studies using this compensatory approach generally report item-specific improvement, they vary regarding generalisation to untreated items (Beeson & Hillis, 2001; Rapp & Kane, 2002). Since a functional motive underlies GK's therapy plan, it is important that he is ultimately able to internalise and employ the strategy in his own everyday communicative activities. Therefore, the following questions will be considered post-therapy:

1. Has GK learnt to use the keyword relay strategy in the therapy task?
2. Have GK's skills in using the strategy generalised to untreated items in a similar task?
3. Have improvements in his skills using the strategy generalised to other tasks requiring sound-to-letter mapping?
4. Have improvements in his spelling skills generalised to other areas of language processing?

Case Description

GK is a 50 year old gentleman who has suffered two left hemisphere CVAs, the first in January 2003 and the second in the May of the same year. A CT brain scan in January 2003 revealed a large left hemisphere middle cerebral artery infarct, and a scan in May 2003 revealed a second left hemisphere middle cerebral artery infarct. These have resulted in a mild-moderate receptive dysphasia, a severe expressive dysphasia, severe verbal dyspraxia, a right hemiparesis and epilepsy.

Prior to his strokes, GK was an accountant in the City and often travelled on business. He has an English father and a French mother and was brought up bilingually; he also spoke fluent German and Dutch. He was highly computer literate and was in the process of writing a novel.

GK's cognitive and language skills were assessed in October 2005. Table 1 displays a summary of his performance on the Comprehensive Aphasia Test (CAT) (Swinburn, Porter & Howard, 2004) (for full details see Appendix 1).

Table 1

Comprehensive Aphasia Test[1]: a summary of GK's results

	Raw score
Cognition	35/38
Receptive language	
Comprehension of spoken language	44/66
Comprehension of written language	55/62
Expressive language	
Repetition	37/74
Naming	17
Spoken picture description	6
Reading aloud	15/70
Writing	32/76
Written picture description	0

[1] The CAT is standardised on 266 test results from unselected people with aphasia (mean = 50, standard deviation = 10).

	Raw score
Disability questionnaire	
Disability	31½/64
Impact	9½/60

Cognition

GK scored 36/36 on the Coloured Progressive Matrices (Raven, 1976) (>95th percentile), indicating that he has good non-verbal visual problem-solving abilities. On the CAT he performed well on the recognition memory task (10/10) and semantic memory task (9/10). With respect to short-term memory, he had difficulty repeating a string containing more than three digits (4/14). However, his spoken output difficulties may have contributed to this poor performance.

Receptive language

GK has good auditory and written comprehension of single words (28/30), but has difficulties at the sentence level (14/32 and 17/32 respectively). However, using a text-to-speech software package such as 'ReadPlease' has been found to increase his written comprehension.

Expressive language

GK has single phrase level telegrammatic speech which is characterised by multiple groping for sounds and articulatory errors. These include problems with voicing and difficulties discriminating between /h/ and vowel sounds. He also has word-finding difficulties and sometimes produces semantically-related words. When asked to describe the CAT composite picture, he said: 'There's a bowl.../dækt/...cat.../bou...bouɸ/...man...down...ok.../bədəl/...man...look... /boulbi...tɒkiŋ nat/'. He is able to name some objects (14/48) and actions

(2/10). He can read aloud some simple single words (9/48), including function words (6/6), but he is unable to read aloud complex words or nonwords.

GK has severe dysgraphia. He is able to copy letters and words in both the same and cross case (27/27), and write more automatic items such as his name. He scored very poorly on the CAT written picture naming subtest (3/21 letters correct in the correct position), responding as follows:
boy → no response
eye → U, self-corrected to E
pear → A, self-corrected to O which he then rejected
tank → A
giraffe → F, self-corrected to GI

Writing to dictation is also extremely difficult for GK (2/28 letters correct in the correct position):
man → M
yacht → YO
idea → no response
undrinkable → N
blosh (nonword) → Duc

For the CAT composite picture he wrote: '*Ca book of*'.

Psychosocial well-being

GK's responses to the CAT Disability Questionnaire reveal that, since his strokes, he is able to understand others as easily as before, and he finds talking and reading moderately difficult and writing very difficult. His responses indicate that his communication difficulties have a moderate impact on his everyday life, but that they do not affect his self-image or emotional well-being.

GK is highly motivated to work on his communication skills. For the past two years he has regularly attended both individual and group therapy sessions. Whilst he has identified speaking, reading, writing and using the computer as his priorities for therapy, GK's one specific goal is to improve his spelling skills so

that he can correspond with his friends by email, with the aid of a word prediction software package.

Recent therapy has focussed on increasing GK's awareness of phonological and orthographic patterns with a view to begin working towards developing his spelling skills. A set of pictorially represented rhyming words was used to improve GK's phoneme segmentation and blending skills and to increase his ability to discern where sounds occur and change in a word. Letter and rhyme charts have also been employed, and a restricted choice of response items given if necessary. An errorless learning pattern has been integrated wherever possible in order to build and strengthen accurate representations within GK's language processing system. Latterly, in order to focus on word-initial letters in spelling, a keyword picture letterboard has been introduced in an attempt to aid accurate mapping of sounds to letters. Here, each letter of the alphabet has been represented pictorially by one 'keyword', for example: A = Ant, B = Bat (for the full set of keywords see Appendix 2). Wherever possible, each keyword picture name is monosyllabic, high frequency, contains 3 or 4 letters/sounds and has a regular spelling with a single word-initial phoneme. It is from this point, three years post-onset, that the therapy outlined in this study begins.

Pre-therapy investigations

From GK's performance on the spelling subtests of the CAT it can be hypothesised that both his lexical and sublexical spelling skills are impaired. GK has been learning to associate each letter of the alphabet with a keyword picture/name, with a view to developing a keyword relay strategy for sound-to-letter mapping. In order to gain a clearer picture of both his pre-therapy spelling abilities and his future potential for using a keyword strategy further assessments were performed. The results of these are detailed below (significance values reported in this section are all two-tailed). All pre-therapy spelling assessments were carried out without the keyword picture sheet.

Lexical spelling

Whilst GK has very limited ability to spell words, he was able to write some first letters correctly on the CAT. As these included the first letters of the irregular words *eye* and *giraffe* it can be hypothesised that he has at least some limited access to representations in the graphemic output lexicon. To investigate this further, GK was randomly presented with 16 individual pictures, six of which had names beginning with the letter K (ie 4 x K and 2 x KN), four of which began with the letter C and the rest of which began with a different letter. GK was asked to identify which pictures began with the *letter* K. He correctly identified 4/6 items (including the two items beginning with KN), but also selected a picture beginning with the letter D. For a number of items he attempted to segment off the first sound. While GK may have some retained orthographic knowledge, access to this would appear to be inconsistent.

Nonword spelling

GK's response to the single nonword spelling item in the CAT bore no relationship to the target. He found the PALPA 45 nonword spelling test (Kay, Lesser & Coltheart, 1992) so difficult that this was discontinued after 16 items. He scored 0/16. He was able to accurately write 3/16 (19%) first letters but did not get any letters in subsequent positions correct.

It is of relevance to note that GK's nonword spelling performance compares closely with his nonword reading abilities. He scored 0/16 on the PALPA 36 nonword reading test (Kay et al, 1992), although his poor performance on this task was possibly exacerbated by his articulatory difficulties. It can be concluded that GK has severely compromised sublexical reading and spelling skills.

Writing single letters

GK writes the alphabet with ease in both upper and lower case letters. However when asked to write the letter given the letter name, he scored only 6/10 (60%).

Single sound-to-letter mapping

Three single sound-to-letter mapping tasks were presented (see Table 2). The mapping investigated was always the most common sound-to-letter correspondence. For the five vowels, the short vowel pronunciation was used. Three letters of the alphabet were excluded: Q and X as they are not represented by straightforward sound correspondences, and one of C/K since only one phoneme is required to represent these letters.

Table 2

Pre-therapy results: single sound-to-letter mapping tasks

Writing the letter when given the letter sound	8/23 (35%)
Pointing to the letter when given the letter sound	
restricted choice	16/23 (70%)
full choice	2/23 (9%)

GK had difficulties writing the letter when given the letter sound. When he was given the letter sound and asked to point to the corresponding letter, his performance was very poor when he was selecting from the full alphabet layout. He was significantly better on a subsequent task where response choice was

restricted to a set of four letters (McNemar, n=23, $p<0.001$). For the latter task, materials were taken from PALPA 23 (Kay et al, 1992).

Initial sound segmentation: keyword pictures

GK was randomly presented with the 26 keyword pictures depicted in the alphabet picture chart which he had been using in previous therapy (see Appendix 2), and he was asked to say the first sound of each word. GK did this by verbally naming the picture before segmenting the first sound (he was able to name all items successfully). Due to his articulation difficulties, two scoring systems were applied to his production of word-initial sounds:

a) Lenient scoring, ie segmentation of the first sound as he was producing it in the whole word: 24/26 (92%)
b) Strict scoring, ie recognisably accurate production of the phoneme in isolation: 16/26 (62%)

This indicates that, despite his articulation difficulties, GK is able to segment the initial sounds of his keywords; however this may not be recognisable to the listener as the target phoneme.

Initial letter identification and writing: keywords and matched control items

A series of assessments investigating GK's ability to point to word-initial letters and to write words, both to dictation and when picture naming, were carried out (see Table 3). The set of keywords which he had been learning to associate with the alphabet were matched to an untreated set of control words in terms of overall number of graphemes and word frequency (see Appendix 3). Due to difficulty finding high frequency, 3-5 letter words beginning with O, Q, U, X and Y, these letters were excluded from the control tasks. These items were also omitted from keyword data in selected statistical analyses to allow for matched keyword-to-control comparisons (n=21). Since GK had not seen the control pictures before, this picture set was randomly presented to him prior to assessment, and he was told which name was being given to each picture.

In order to avoid influencing assessment scores through the repetition of the same vocabulary in a single session, tasks requiring the same vocabulary were presented across separate sessions, ie each word was presented only once in a given session. Picture naming tasks preceded tasks containing the same items to dictation. In order to avoid fatigue, tasks of a shorter duration were presented where possible by splitting the keyword and control lists during the session, with half the set being presented to dictation and the other half for picture naming; these were then reversed in the following session. Items in each keyword and control task were presented in a different random order on each occasion. For the 'restricted choice' letter pointing tasks GK was given 4 letters to choose from. His results in the writing tasks were scored in two ways: whether he correctly wrote the whole word, and whether he correctly wrote the first letter.

Table 3

Pre-therapy results: pointing and writing tasks when picture naming and to dictation for keywords and untreated control items

	Keywords	**Control items**
Pointing to initial letter: to dictation		
restricted choice	n/a	17/21 (81%)
full choice	26/26 (100%)	6/21 (29%)
Pointing to initial letter: picture naming		
restricted choice	n/a	14/21 (67%)
full choice	26/26 (100%)	11/21 (52%)
Writing to dictation		
initial letter	25/26 (96%)	9/21 (43%)
whole word	4/26 (15%)	0/21 (0%)
Written picture naming		
initial letter	24/26 (92%)	14/21 (67%)
whole word	2/26 (8%)	0/21 (0%)

An analysis of GK's performance reveals that he is consistently able to successfully point to the initial letter of keywords from the full alphabet keyboard, both to dictation and when picture naming. The fact that he is significantly more successful on both of these tasks with the keywords than the matched controls

(McNemar, n=21, $p<0.001$ and $p<0.05$ respectively) confirms that he has successfully learnt to associate the keywords to the appropriate letter. Whilst he has only limited ability to write the entire keyword either when writing to dictation or when written picture naming, he generally wrote the first letter of the name accurately in both tasks. His ability to write first letters is more accurate for keywords than controls, but this comparison is only statistically significant for the dictation task (McNemar, n=21, $p<0.05$).

For the control words, in the pointing to dictation task GK is able to point to some initial letters, but his performance is significantly better when he is given a restricted choice (McNemar, n=21, $p<0.05$). In the picture naming version of this task, the benefit of restricted letter choice failed to reach statistical significance (McNemar, n=21, ns). GK is able to write some initial letters of control words, both to dictation and when picture naming, but he is unable to write any control words in their entirety.

Initial letter identification: Boston Naming Test pictures

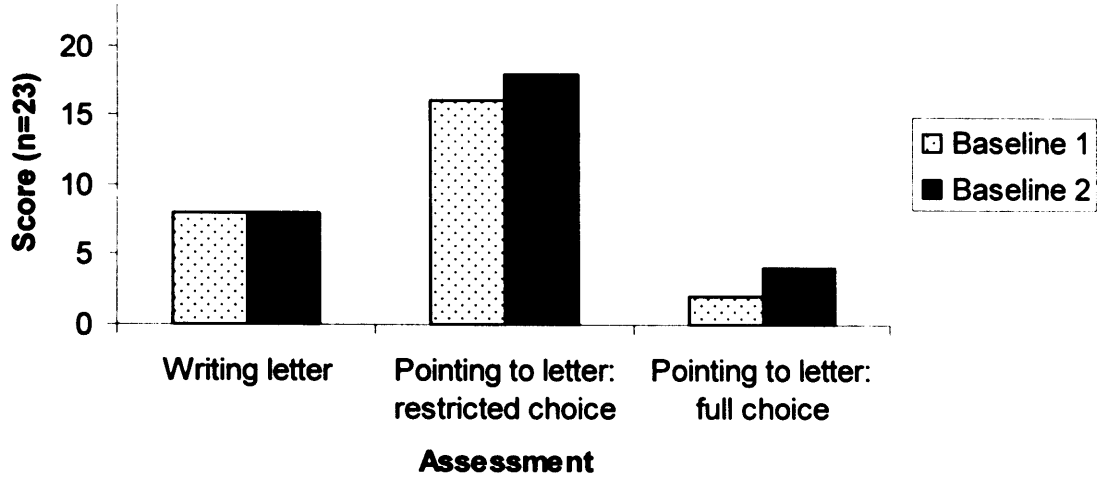
The Boston Naming Test picture stimuli (Kaplan, Goodglass & Weintraub, 1983) were used to investigate GK's pre-therapy ability to point to the initial letter of more complex words (eg words containing word-initial clusters or polysyllabic words) using the full alphabet keyboard (see Appendix 4 for the full word set). Again, there were two conditions: pointing to dictation and picture naming. In the picture naming version, he correctly identified the initial letter of only 2/60 (3%) pictures, despite producing a recognisable spoken attempt at the name for 24/60 (40%). When the words were dictated to him he scored 5/60 (8%). This task used the full alphabet keyboard. It is therefore possible to attribute some of his difficulties with this task to difficulty selecting from the full alphabet.

Pre-therapy stability of performance

In order to investigate stability of performance pre-therapy, repeated baselines were obtained on three measures after a period of 8-10 weeks. As Figure 2 shows, there was minimal difference between GK's repeated baseline scores, confirming that his pre-therapy performance was stable.

Figure 2

Repeated baselines: single sound-to-letter mapping tasks



Summary of pre-therapy investigations

These pre-therapy investigations indicate that, although GK has severe lexical and sublexical spelling difficulties, he possesses some valuable skills on which he will be able to base and develop his keyword relay strategy during therapy. For example, he is consistently able to name all of his keyword pictures, has some initial sound segmentation abilities and has learnt to link the keyword pictures to the alphabet. Despite his difficulties selecting from the full alphabet when linking novel items to their initial letters, the benefit of employing a relay strategy lies in the fact that he will be selecting from the full alphabet for keywords, which he is consistently able to do. His performance is broadly stable.

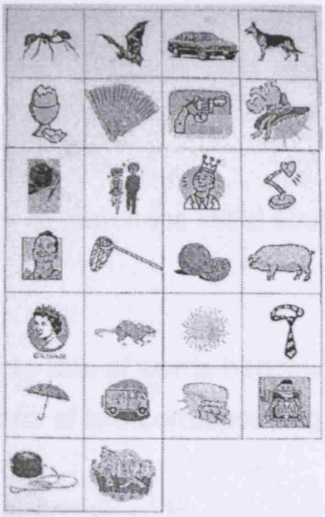
Some potential challenges which GK may face in therapy have also been revealed, such as his inconsistent segmentation skills which are exacerbated by his articulation difficulties, and his difficulties naming some novel pictures.

Therapy

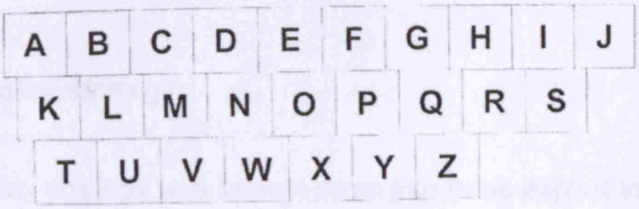
Materials

In the therapy sessions, the following materials were used:

- ***Keyword picture sheet***: arranged alphabetically on an A4 sheet in portrait layout



- ***Keyboard letterboard***: arranged alphabetically on an A4 sheet in landscape layout
  This was adapted to the QWERTY format in the latter stages of therapy (following the same layout as before).



- ***Therapy picture set***: individual picture cards (4.5cm x 4.5cm)
  The 145 pictures in the therapy set were taken from Microsoft Clip Art. All picture names were restricted to the same simple word-initial sound-to-letter

correspondences as the keywords (eg A = /æ/ not /eɪ/; C = /k/ not /s/). No word-initial clusters were permitted. More items were available for some letters than others (see Appendix 5). In the latter stages of therapy, photographs of GK's family, friends and favourite places were introduced, eg Dad, Paris. The 145 items ranged between 3 and 10 letters in length (mean = 4.2) and contained between 1 and 4 syllables (mean = 1.3).

- ***Response sheet***: to record GK's verbatim response for each stage of the strategy

Additional materials used in the homework were as follows (see Appendix 6 for examples):

- ***Picture matching tasks***: to match the initial sound of a picture name to its corresponding keyword

- ***Listening lists***: to listen to lists of words beginning with one or other of two phonemes and point to one of two corresponding keyword pictures

Procedure

Therapy was carried out in a total of 10 sessions over 14 weeks. Errorless learning was promoted as far as possible in order to aid retention of the correct mapping patterns and to maintain motivation by facilitating success through the giving of cues as necessary.

The keyword relay strategy

The keyword relay strategy was broken down into three explicit stages. Each stage was worked through for one item before moving on to the next item:

Stage 1 Name a picture (eg *house*) and segment the initial sound of the picture name (eg *house* = /h/)

If GK had difficulty naming the picture, semantic cues were given followed by the picture name if necessary. If difficulties were encountered segmenting the initial sound of the word, GK was asked to listen carefully to the student's production of the word and then say the first sound; if further support was required, he was given the sound and asked to copy it.

Stage 2 Match this initial sound to its corresponding keyword picture from the whole set (alphabetical layout) (eg /h/ = *hat*)

If GK had difficulty selecting the keyword picture, his choice was restricted by indicating which row the target picture was in.

Stage 3 Match the keyword to its corresponding letter on the letterboard (A-Z keyboard layout) (eg *hat* = H)

If GK had difficulty matching his keyword picture to its corresponding letter, he was given a restricted choice of letters to select from.

Verbatim responses were recorded and a quantitative score was given for each stage of the strategy within each therapy session. Since a sound-based strategy was being employed, both letters C and K were accepted as correct for words beginning with the phoneme /k/.

Outline of a therapy session

a) *Feedback about the previous week's homework*

b) *'Warm-up' segmentation task*
GK was randomly presented with his individual keyword pictures, and asked to say the first sound of the picture name.

c) *Practise the keyword strategy (as above)*
Pictures were selected from across the full range of the alphabet. In each session, whilst some items came from the previous week's homework set, many had not received recent practice. As therapy progressed, the number of items

practised each week increased from n=10 (Session 1) to n=19 or 20 (Session 4 onwards).

d) *Set homework tasks*

1. Look at the keyword pictures in random order, and say the first sound of the name
2. Practice the keyword strategy
   GK took 24 individual picture cards home (selected to ensure that some had been practised in the therapy session, and others not). The written instructions stated that he should randomly select 8 pictures each day, and for each item:
   i) Think about the sound which the picture name begins with
   ii) Find the keyword which starts with the same sound
   iii) Find the corresponding letter on the letterboard

GK carried out his homework regularly with support from a close relative.

Modifications as therapy progressed

Focus on specific sound contrasts

In the first five sessions, therapy items were selected from across the full alphabet. After monitoring GK's progress, it became clear that his production difficulties were interfering with his ability to segment and map sounds to letters (Stages 1 and 2 of the therapy strategy). Most noticeably, he had difficulties producing appropriate voiced/voiceless contrasts for plosives and fricatives, and accurately producing continuants such as /h/ and /r/. From Session 6, explicit work on specific sounds was integrated into each therapy session. To focus in on specific sound contrasts, a listening task was introduced following the warm-up task in each session. Pairs of phonemes were selected, and the spoken names of all the therapy items that began with those phonemes ('listening lists') were presented to GK in random order. The keyword pictures corresponding to the two phonemes were placed on the table. GK was asked to listen to each word and point to the keyword that began with the same sound. When moving on to strategy practice, whilst always including a range of word-initial phonemes,

approximately half of the items in any given session began with the targeted phonemes. Initially, focus was on contrasts between voiceless plosives, then voiced plosives. In the final sessions, voiced/voiceless plosive contrasts were introduced: b/p, d/t, g/c-k.

Additional homework tasks were given to reinforce the sound contrasts introduced in the therapy session (see Appendix 6). GK was given picture sheets containing one keyword picture and two (increasing to four) pictures from his therapy set. The task was to select which therapy picture/s begin with the same sound as the keyword picture. He was also given the appropriate 'listening lists' for his relative to present, as described above. The 24 pictures selected for strategy practice included both a range of initial phonemes and a high proportion of items beginning with the targeted sounds.

Introduction of the QWERTY keyboard layout

Since GK was consistently successful using the alphabetical keyboard letterboard at Stage 3 of the strategy, in Session 6 the speed at which he could match his keyword pictures to their corresponding letters using this alphabetical layout and a QWERTY keyboard sequence was compared. Having attained 100% matching his keyword pictures to the QWERTY keyboard format and having taken only 3 seconds longer to do this, the QWERTY keyboard letterboard was integrated into therapy from Session 7.

Results

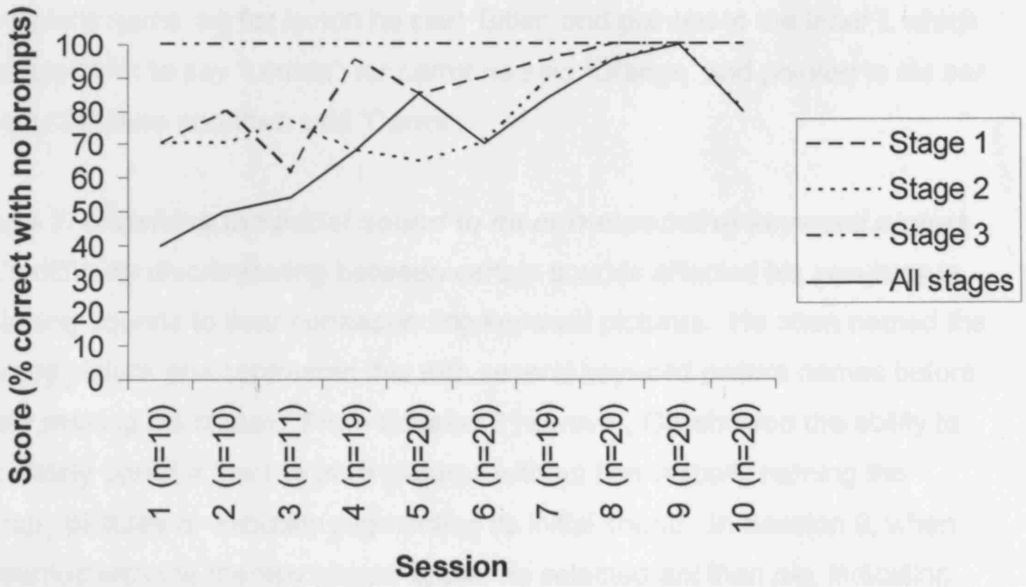
In order to evaluate the effectiveness of therapy, GK's progress using the keyword relay strategy was monitored in each therapy session. Post-therapy, he was reassessed on a number of measures to investigate whether or not improvements had generalised to untreated items and/or to untreated tasks.

GK's progress during therapy

GK's progress was recorded for each stage of the strategy within each therapy session. Figure 3 below displays how his performance changed over the therapy period and refers to the number of items which he successfully attained without requiring any prompts. The figure indicates the percentage correct for both each individual therapy stage and the entire strategy ('All stages').

Figure 3

GK's progress on each stage of the strategy during the therapy period



Initially, GK was encouraged to explicitly perform all three components of the strategy. There was little quantitative or qualitative evidence of progress in Stages 1 and 2 of the strategy during Sessions 1 to 5. Once restricted sound

sets were introduced into therapy from Session 6, GK's performance began to improve. Support during Stage 3 of the strategy was not required for any item during the therapy period. As therapy progressed, there was increasing evidence that GK was internalising the strategy since his performance during each stage became more implicit.

Stage 1: Naming a picture and segmenting the initial sound of its name

Initially, GK had considerable difficulties segmenting the initial sound of words, particularly differentiating between voiced vs voiceless plosives and /h/ vs vowels. He often required prompts to make sounds 'noisier' or 'quieter' depending on their voicing characteristics. Working on restricted sound sets in Sessions 6 to 10 led to improvement in these segmentation skills. From Session 6 he showed increased confidence in giving the initial sound without first verbally naming the picture; moreover, on occasions he selected the correct keyword picture without first verbally giving its initial sound. Where segmentation was not explicit but he selected the correct keyword picture or proceeded straight to select the correct letter, it was assumed that he could segment the initial sound correctly, and this was scored accordingly. From Session 8 GK began to self-cue if he had difficulties naming the picture, by first identifying the letter and then working backwards through the stages to retrieve the picture name, eg for *lemon* he said 'Bitter' and pointed to the letter L which prompted him to say 'Lemon'; for *carrot* he said 'Orange' and pointed to his *car* keyword picture and then said 'Carrot'.

Stage 2: Matching the initial sound to its corresponding keyword picture

GK's difficulty discriminating between certain sounds affected his accuracy in matching sounds to their corresponding keyword pictures. He often named the therapy picture and contrasted this with several keyword picture names before finally making his choice. From Session 6 however, GK showed the ability to accurately select a few keyword pictures without first verbally naming the therapy pictures or explicitly segmenting its initial sound. In Session 9, when presented with the therapy picture *apple*, he selected *ant* then *pig*, indicating that the strategy was beginning to generalise to sounds and letters beyond word-initial position. Further internalisation was in evidence on occasions when GK looked at picture and pointed to the letter, without using the keyword relay. Whilst GK showed an overall improvement in this stage of the strategy, the dip

at the end of the therapy period from 100% to 80% accuracy reveals that this skill remained slightly unstable.

Stage 3: Matching the keyword to its corresponding letter on the letterboard

This was a strength for GK pre-therapy, and throughout the therapy he was able to perform Stage 3 with no problems, even when the QWERTY keyboard layout was introduced in Session 7.

In addition to the improvements seen in the individual stages across therapy sessions, the proportion of items for which GK successfully completed all stages of the strategy increased.

Listening tasks using restricted sound pairs

The table in Appendix 7 shows the pairs of phonemes which were explicitly worked on in the listening tasks during Sessions 6 to 10 and the results reveal GK's consistently high performance. However, GK continued to report difficulties 'hearing' whether words began with /t/ or /d/ and /k/ or /g/. Items with an unstressed word-initial syllable also posed difficulties throughout therapy, eg *tomato*, *computer*.

These therapy results strongly indicate that, by the end of the therapy period, GK was successfully using the keyword relay strategy in the therapy task. Moreover, there is evidence that he was beginning to internalise each stage of the strategy, and that this was beginning to extend to sounds and letters beyond word-initial position.

Post-therapy reassessment

As before, no cues were given during assessment and GK was not provided with the keyword picture sheet. Only tasks involving the full letter choice were performed. Due to developments during therapy, the QWERTY keyboard letterboard was used as opposed to the pre-therapy alphabetical letterboard.

Since an improvement on the pre-therapy results was predicted, all statistics comparing pre- and post-therapy scores are one-tailed.

GK was observed to segment some items and name some of his keywords from memory within each task. As his keyword pictures were not available for reference, any significant improvements reported below indicate that he was successfully internalising the strategy.

Tasks in which GK was required to point to the correct letter on the full QWERTY keyboard layout will be reported first. These will be followed by the results of the writing tasks.

1. Pointing tasks

a) Picture naming: untreated items

For this task, GK was presented with the n=21 untreated control pictures in random order and asked to think of the picture name and point to its initial letter. While GK's pre-to-post-therapy scores increased marginally from 11/21 (52%) to 13/21 (62%) this was clearly not a significant increase. However, it should be noted that GK's pre-therapy score was surprisingly good on this assessment. This will be discussed later in the paper.

b) Dictated words: untreated items

Two sets of words were presented: the names of untreated control pictures, and the names of the Boston Naming Test pictures. In each case, GK listened to the list of names, presented in random order. The task was to point to the first letter of the word.

His score on the untreated control items improved significantly from 6/21 (29%) pre-therapy to 13/21 (62%) post-therapy (McNemar, n=21, $p<0.05$). Despite GK's improvement in this task, his performance when pointing to the initial letter of the matched keyword remained significantly better (McNemar, n=21, $p<0.05$).

This reveals that his ability to point to the initial letter of control words is not yet as consistent as that shown on the same task with keywords.

Significant improvement was also seen for the BNT picture names, whereby his score increased almost seven-fold: pre-therapy, 5/60 (8%); post-therapy, 34/60 (57%) (McNemar, n=60, $p<0.001$).

c) Single sound-to-letter matching

GK was given a phoneme and asked to point to its corresponding letter. Pre-therapy, he had scored 2/23 (9%) and 4/23 (17%) on the repeated baselines. His post-therapy score of 18/23 (78%) showed a significant improvement (McNemar, n=23, $p<0.001$; comparing his second baseline with his post-therapy score). For the majority of items he explicitly used his keyword relay strategy, verbally repeating the sound and naming its corresponding keyword before pointing to the letter; for all other items he simply repeated the sound and pointed to the letter. This indicates that implicit generalisation of the strategy has taken place at the single sound level.

2. Writing tasks

Writing tasks were scored in two ways: whether the first letter was correct, and whether the whole word was correct.

a) Written picture naming

Two sets of pictures were presented in random order: the keyword pictures and untreated control pictures. GK was asked to write down the picture name.

Table 4

Post-therapy results: written picture naming

		1st letter correct	Whole word correct
Keyword pictures	Pre-therapy	24/26 (92%)	2/26 (8%)
	Post-therapy	26/26 (100%)	11/26 (42%)*
Control pictures	Pre-therapy	14/21 (67%)	0/21 (0%)
	Post-therapy	15/21 (71%)	5/21 (24%)*

* = significant improvement pre- vs post-therapy (McNemar, $p<0.05$)

i) Keyword pictures

GK's keyword written picture naming skills have maintained, and even improved, throughout the therapy period.

ii) Control pictures

GK's pre-to-post-therapy initial letter score increased marginally. (As with the equivalent pointing task, his high pre-therapy score will be discussed later in the paper.)

The significant improvement in GK's pre-to-post-therapy whole word scores* indicates that generalisation of the strategy has occurred for letters beyond word-initial position in both keywords and untreated control items.

b) Written picture description: connected writing

GK's post-therapy CAT written picture description response consisted of '*Cat of filo ha_. Fish is cat. Man _*'. This contains over twice as many words as his pre-therapy response of '*Ca book of*'. Interestingly, the three nouns he spelt accurately post-therapy also appeared in either his keyword or control word set. While the data is limited, it may be an indication that GK is beginning to generalise his improved sound-to-letter mapping skills to connected writing.

c) Writing to dictation

Three sets of words were presented: the names of keyword pictures, the names of untreated control pictures, and the n=16 PALPA 45 nonwords. GK was asked to listen to the word and write it down.

Table 5

Post-therapy results: writing to dictation

		1st letter correct	Whole word correct
Keyword picture names	Pre-therapy	25/26 (96%)	4/26 (15%)
	Post-therapy	26/26 (100%)	13/26 (50%)*
Control picture names	Pre-therapy	9/21 (43%)	0/21 (0%)
	Post-therapy	19/21 (90%)**	6/21 (29%)***
Nonword spelling	Pre-therapy	3/16 (19%)	0/16 (0%)
	Post-therapy	9/16 (56%)	0/16 (0%)

* = significant improvement pre- vs post-therapy (McNemar, $p<0.05$)
** = significant improvement pre-vs post-therapy (McNemar, $p=0.001$)
*** = significant improvement pre- vs post-therapy (McNemar, $p<0.05$)

i) Keywords

GK's first letter scores have maintained their high level throughout the therapy period. His significantly improved performance at the whole word level* indicates that generalisation of the strategy has taken place for letters beyond the word-initial position in dictated keywords.

ii) Control words

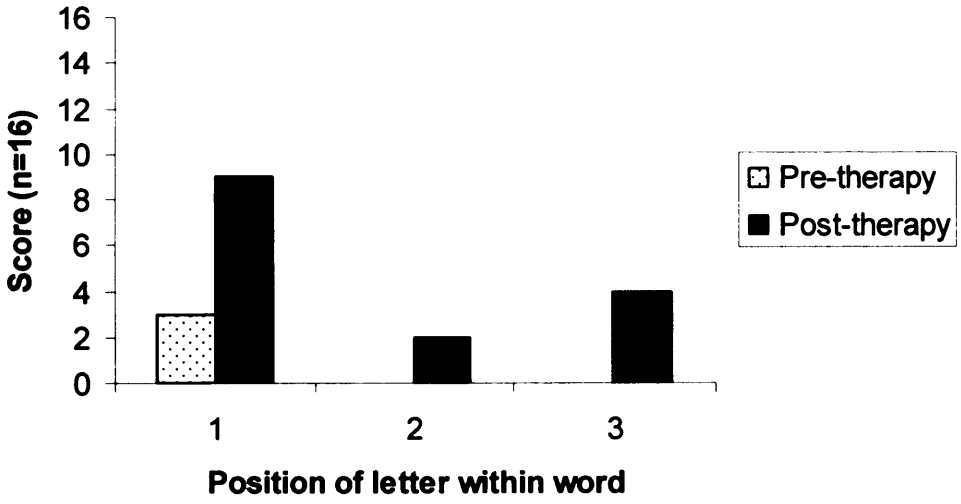
GK's initial letter score for untreated items approximately doubled post-therapy, marking a significant improvement**. A significant improvement was also seen at the whole word level***. This signifies that the strategy has generalised to his writing to dictation of untreated items, for letters in word-initial position and beyond. Indeed, his ability to write the initial letter of dictated untreated items now equals that of dictated keywords (McNemar, n=21, ns). However, his skills at writing the whole word to dictation remain significantly higher for keywords than for untreated items (McNemar, n=21, $p<0.05$).

iii) Nonword spelling

Post-therapy, GK remained unable to write any whole nonwords. Figure 4 below displays GK's improved pre-to-post-therapy performance in writing first, second and third letters. Whilst his ability to write the initial letter improved considerably, this was not sufficient to reach statistical significance (McNemar, n=16, ns). His post-therapy second letter score was lower than his third letter score, possibly signifying the additional difficulty which vowels, often featuring in second position, pose over consonants.

Figure 4

Pre- and post-therapy results: nonword spelling



3. Nonword reading

GK's nonword reading score (PALPA 36) remained 0/16. Whilst his ability to accurately target the initial sound increased from 10/16 (63%) to 14/16 (88%), there was evidence of slightly more lexicalisation post-therapy. GK's sublexical reading skills have therefore not improved.

Summary of results

Having strengthened GK's phoneme-to-grapheme conversion skills through the use of the keyword relay strategy, and having observed GK overtly using this strategy during post-therapy assessments, these results provide sound evidence

that GK has learnt to use the strategy both in the context of the therapy task itself and through its internalisation in other more varied spelling tasks. His performance has improved not only on pointing/picture naming tasks, but also on writing to dictation tasks, and not only on word-initial sound-to-letter mapping, but also on the mapping of sounds to letters contained further within a word. There was no apparent benefit to nonword reading.

GK himself was certainly convinced of the benefit of the therapy. Towards the end of the therapy period, he reported that he thought he was now able to produce 'more words' in spontaneous speech and that he was finding it easier to read. A close relative endorsed GK's report and added that she felt his speech was becoming more intelligible.

Discussion

Since GK did not have his keyword picture sheet available for reference during post-therapy assessment, all post-therapy tasks were stringent investigations of his ability to generalise the strategy. GK's significantly improved results show that his keyword relay strategy has generalised to non-therapy items and tasks. The extent of this generalisation will be investigated below in reference to the questions raised at the beginning of this paper.

1. Has GK learnt to use the keyword relay strategy in the therapy task?

GK's progress during therapy demonstrated that he had not only become increasingly successful at explicitly using the keyword relay strategy in the therapy task, but that he had also begun to internalise it. He required less verbalisation of the picture name, its initial sound or the keyword, occasionally carrying out all stages of the strategy in silence. At times he was able to successfully point to the letter without explicitly using the keyword picture as a link. The strategy also resulted in improved self-cueing of the picture name when spoken word-finding was difficult, and there was evidence of spontaneous generalisation to sounds and letters beyond word-initial position. Drawing on GK's relatively strong auditory discrimination skills to focus on the phoneme distinctions which he found difficult to accurately produce proved to benefit the segmentation and sound-to-keyword matching stages of the strategy. GK's skill at using the keyboard layout, particularly the QWERTY format, indicates that he was not simply matching the keyword picture to its corresponding letter spatially, rather that the link between sounds and letters had been firmly established.

2. Have GK's skills in using the strategy generalised to untreated items in a similar task?

When GK was presented with an untreated picture, asked to think of its name and point to its initial letter, there was no significant improvement in his pre-to-post-therapy score. It therefore appears that there has been no generalisation of the strategy to untreated items in a task similar to that used in therapy.

Nevertheless, his pre-therapy score on this task was surprisingly high. Whilst this indicates that he had some word-initial sound-to-letter links pre-therapy, when compared with other pre-therapy results it also suggests that his performance was somewhat variable, despite repeated pre-therapy baseline measures for single sounds implying the contrary. Reasons for this are unclear, although the potential for a practice effect, whilst unlikely, does exist. Fatigue was also noted to have a considerable effect on GK's performance throughout the therapy period; it is possible that this may have impacted his post-therapy performance on this task.

Evidence from other tasks (discussed below) indicates that the strategy has indeed generalised and substantiates this particular score as an anomalous result.

3. Have improvements in his skills using the strategy generalised to other tasks requiring sound-to-letter mapping?

There is no doubt that generalisation has taken place to other sound-to-letter mapping tasks. For all tasks there was qualitative evidence of both explicit and implicit use of the strategy.

Generalisation of the strategy was evident in tasks requiring single sound-to-letter matching, pointing to the initial letter of both dictated control words and the more complex dictated BNT picture names, and writing the initial letter of untreated control words to dictation. The strategy was also seen to generalise beyond word-initial position to whole word writing to dictation and written picture naming tasks, and resulted in an increase in the amount of whole words which GK was able to spontaneously write to describe a picture.

GK's ability to accurately write the first letter of nonwords improved (although this did not quite reach statistical significance); post-therapy, he was also observed to accurately attempt some second and third letters, reflecting his improved segmentation and sound-to-letter mapping skills.

4. Have improvements in his spelling skills generalised to other areas of language processing?

Since no improvement was observed on the nonword reading task, generalisation of the strategy was proven to be restricted to spelling. This provides evidence for a specific therapy effect – that his improved skills were a result of the successful internalisation of the keyword relay strategy for spelling, as opposed to some more general benefit of regular therapy contact.

Evaluation of the study

Employing a cognitive neuropsychological approach, in which GK's progress was monitored before, during and after therapy, enabled timely identification of his strengths and difficulties to ensure that therapy was consistently relevant and client-centred, and permitted robust statistical analyses within and between items and tasks to evaluate the efficacy of therapy (RCSLT, 2005; Whitworth et al, 2005). The complex nature of GK's pre-therapy spelling difficulties and his abilities to work with the compensatory strategy justified a sublexical approach to his dysgraphia therapy (Rapcsak & Beeson, 2000), the efficacy of which has been proven above.

Whilst GK's original therapy plan focused solely on developing his use of the keyword relay strategy, during early sessions particular difficulties came to light regarding his production of certain voiced and voiceless contrasts at the segmentation stage of the strategy. Therefore, therapy was adapted to incorporate listening tasks in order to facilitate progression of the strategy. Working on restricted sound sets in this way was shown to be a successful means of improving his segmentation skills. Pre-therapy investigations on his keywords indicated that GK could successfully segment the initial sound and select its corresponding letter from the full alphabet. However, had his production of voiced and voiceless contrasts been investigated further, the original therapy plan would have incorporated the need to treat these pre-requisite phonological segmentation skills. Beeson and Hillis (2001) suggest training consonants in sets of five at a time according to their frequency; this may have been a more efficient approach for GK.

The accessible strategy design, together with GK's motivation and family support, facilitated practice outside of therapy sessions. The combination of regular therapy with near daily homework provided the repetitive practice necessary for establishing and generalising the strategy; such intensive stimulation was also endorsed by Beeson et al (2000) in their study of SW.

Whilst the therapy picture set was extensive and included personally relevant items, GK's motivation could have been further enhanced had even more highly imageable, short words containing simple sound-to-letter correspondences been available. However, due to these strict criteria it was not possible to expand the therapy set further, and, despite endeavouring to systematically assign items for therapy and homework, the fact that more pictures were available for some letters than others meant that he inevitably gained more practise with certain sounds/letters (eg P) than others (eg Y). The few items containing an unstressed word-initial syllable proved problematic and arguably should not have been included in the therapy set.

GK's repeated baselines of single sound-to-letter tasks suggested that his pre-therapy performance was stable, however, observations during therapy and the anomalous result discussed above show that there was some variability. Whilst further repeated baselines, particularly of control word tasks, would have provided clarification, practical restrictions did not permit this.

A more conclusive analysis of whether GK was able to generalise the strategy to untreated items in a task similar to that used in therapy (see Question 2 above) could have been facilitated by an additional post-therapy assessment: pointing to the initial letter of presented control pictures with the keyword picture sheet available. This would have ensured that the only variable to change from the therapy task was the items presented, as opposed to also placing demands on his ability to internalise the strategy.

Had further post-therapy assessments using the keyword picture sheet been conducted, and the results compared to those obtained without the keyword picture sheet, more detailed information could have been gained regarding the extent to which GK had internalised the strategy. Again, this was not feasible within the limited investigation period.

Suggestions for future therapy

Having successfully established simple sound-to-letter correspondences for initial letters, GK could now benefit from some time to consolidate these skills, particularly in relation to the sounds which he finds more challenging (ie plosives, vowels and /h/), so that the strategy becomes thoroughly automated (de Partz, 1986). Reassessment at a later date would confirm whether the notable therapy effects had maintained and were being incorporated into his everyday communication.

It is suggested that subsequent therapy promote sounds/letters in second position, such as vowels and CCVC words, in order to further GK's use of the strategy. Less imageable and less frequent nouns, and verbs, could also be incorporated. GK's computer skills could be integrated into therapy, and phrase completion software such as 'Phraseflash' or 'Gapfiller' could be trialled (Mortley, Simmons, Petheram & Enderby, 1992). This would lead GK a step closer to using software which predicts the intended word from first letters and thereby help to reduce the psychosocial impact of his writing difficulties.

Work on irregular spellings is currently not under consideration. GK's reliance on the sublexical spelling route will enable him to write regular words and attempt plausible spellings of irregular words. This will provide considerable functional benefit.

Conclusion

This study has shown that, despite the relatively long period which has passed since the onset of his dysgraphia, employing a compensatory approach to therapy through a keyword relay strategy has enabled GK to successfully develop sublexical spelling skills. He is now able to accurately select the initial letter of words containing simple sound-to-letter correspondences from a QWERTY keyboard. Indeed, sound evidence has proved that GK has not only learnt to use the strategy within the therapy task itself, but that he has also internalised it, and begun to generalise it to a variety of items and tasks requiring sound-to-letter mapping skills. Previous studies promoting the development of sublexical spelling skills through the use of a keyword relay strategy have

therefore been endorsed by GK's experience. It is hoped that the work undertaken by GK during this study will result in significant gains in his functional communication and quality of life.

Word count: 9868

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Appendix 1

Pre-therapy results: Comprehensive Aphasia Test (CAT)[2]

(Swinburn et al, 2004)

	Raw score	T-score
Cognitive Screen		
Cognition		
Line bisection	0.5	59
Semantic memory	9/10	51
Word fluency	1	43
Recognition memory	10/10	59
Gesture object use	11/12	60
Arithmetic	5/6	57
Subtotal	*35/38*	-
Language Battery		
Comprehension of spoken language		
Words	28/30	58
Sentences	14/32	46
Paragraphs	2/4	43
Subtotal	*44/66*	*47*
Comprehension of written language		
Words	28/30	55
Sentences	17/32	50
Subtotal	*55/62*	*61*
Repetition		
Words	27/32	53
Complex words	6/6	62
Nonwords	0/10	38
Digit strings	4/14	43
Sentences	0/12	39
Subtotal	*37/74*	*47*

[2] The CAT is standardised on 266 test results from unselected people with aphasia (mean = 50, standard deviation = 10). A T-score represents the percentile of the standardised score as follows: 50 = 50th percentile, 60 = 68th percentile, 70 = 96th percentile.

	Raw score	T-score
Naming		
Objects	14/48	47
Actions	2/10	47
Word fluency	1	43
Subtotal	*17*	*46*
Spoken picture description	**6**	**47**
Reading aloud		
Words	9/48	45
Complex words	0/6	40
Function words	6/6	62
Nonwords	0/10	40
Subtotal	*15/70*	*46*
Writing		
Copying	27/27	61
Picture names	3/21	45
To dictation	1/28	44
Subtotal	*31/76*	*47*
Written picture description	**0**	**42**
Disability Questionnaire		
Disability		
Talking	8½/16	56
Understanding	0/16	66
Reading	11/16	46
Writing	12/16	50
Subtotal	*31½/64*	*54*
Impact		
Intrusion	9½/16	50
Self-image	0/16	68
Emotional consequences	0/28	69
Subtotal	*9½/60*	*61*
Disability Questionnaire total	*41/124*	*57*

Appendix 2

Keyword set

GK's keyword set comprised pictures representing the following words and word-initial phonemes (vowels were represented in their short form):

Ant	/æ/
Bat	/b/
Car	/k/
Dog	/d/
Egg	/e/
Fan	/f/
Gun	/g/
Hat	/h/
Ink	/i/
Jig	/dʒ/
King	/k/
Lamp	/l/
Man	/m/
Net	/n/
Orange	/ɑ/
Pig	/p/
Queen	/kw/
Rat	/ɹ/
Sun	/s/
Tie	/t/
Umbrella	/ʌ/
Van	/v/
Wig	/w/
X-ray	/eks/
Yo-yo	/j/
Zoo	/z/

Appendix 3

Keyword and control word sets: matching for number of graphemes and word frequency (Francis & Kučera, 1982)

Keyword	Graphemes	Frequency	Control Word	Graphemes	Frequency
Ant	3	13	Axe	3	19
Bat	3	18	Bed	3	139*
Car	3	393*	Cat	3	42
Dog	3	147*	Door	4	348*
Egg	3	47	Elbow	5	17
Fan	3	34	Fish	4	33
Gun	3	142*	Girl	4	374*
Hat	3	71*	Hand	4	717*
Ink	3	8	Igloo	5	0
Jig	3	8	Jug	3	6
King	4	98*	Key	3	71*
Lamp	4	24	Leg	3	126*
Man	3	2110*	Map	3	25
Net	3	24	Nose	4	65*
Orange	6	15	-	-	-
Pig	3	14	Pin	3	20
Queen	5	51*	-	-	-
Rat	3	10	Ring	4	43
Sun	3	117*	Saw	3	8
Tie	3	27	Toe	3	26
Umbrella	8	11	-	-	-
Van	3	2	Vase	4	15
Wig	3	1	Web	3	6
X-ray	4	16	-	-	-
Yo-yo	4	0	-	-	-
Zoo	3	9	Zip	3	1

The table above shows how keywords and controls were matched according to their number of graphemes and frequency statistics (NB words >50 are considered very high frequency*).

A crude comparison of the characteristics of the keyword and control word sets (keywords without matched words have been omitted, n=21) shows that:

- the keyword list contains slightly shorter words due to a lack of availability of appropriate three-letter control words
- the sets contain an equal number of high-frequency words (where 'high' = >=50, 'mid' = 11-49 and 'low' = <=10)

- the control set contains one more mid-frequency word and one less low frequency word than the keyword set

Number of letters	**3**	**4**	**5**	
Keywords	19	2	0	Includes 1 x 2 syllable
Control words	12	7	2	Includes 2 x 2 syllable

Frequency	**High**	**Mid**	**Low**
Keywords	7	8	6
Control words	7	9	5

In summary, whilst the keyword and control sets are not perfectly matched, they are broadly matched across the alphabet.

Appendix 4

Boston Naming Test picture names

(Kaplan et al, 1983)

1. bed
2. tree
3. pencil
4. house
5. whistle
6. scissors
7. comb
8. flower
9. saw
10. toothbrush
11. helicopter
12. broom
13. octopus
14. mushroom
15. hanger
16. wheelchair
17. camel
18. mask
19. pretzel
20. bench
21. racquet
22. snail
23. volcano
24. seahorse
25. dart
26. canoe
27. globe
28. wreath
29. beaver
30. harmonica
31. rhinoceros
32. acorn
33. igloo
34. stilts
35. dominoes
36. cactus
37. escalator
38. harp
39. hammock
40. knocker
41. pelican
42. stethoscope
43. pyramid
44. muzzle
45. unicorn
46. funnel
47. accordion
48. noose
49. asparagus
50. compass
51. latch
52. tripod
53. scroll
54. tongs
55. sphinx
56. yoke
57. trellis
58. palate
59. protractor
60. abacus

Appendix 5

Therapy picture set: word list

A (n=3)	Ashtray		Horse		Paris
	Apple		House		
	Asparagus		Holly	**Q** (n=0)	-
			Hammer		
B (n=9)	Box			**R** (n=7)	Rain
	Bus	**I** (n=0)	-		Radio
	Banana				Radish
	Bag	**J** (n=3)	Jam		Rabbit
	Bell		Jumper		Raspberry
	Books		Judge		Road
	Belt				Rose
	Biscuits	**K** (n=5)	Kettle		
	B*		Kennel	**S** (n=4)	Sock
			Kiwi fruit		Sandwich
C (n=9)	Candle		Kangaroo		Sausage
	Castle		Kite		Sofa
	Cow				
	Cap	**L** (n=6)	Lettuce	**T** (n=11)	Tent
	Computer		Ladder		Tomato
	Camera		Lion		Telephone
	Cake		Lemon		Torch
	Carrot		Leaf		Toilet
	C*		Leeks		Toothbrush
					Table
D (n=5)	Duck	**M** (n=7)	Mountain		Teeth
	Diary		Mushrooms		Tennis
	Dart		Moon		Tintin
	Dad		Mouth		Turkey
	D*		Mug		
			Monkey	**U** (n=0)	-
E (n=1)	Envelope		M*		
				V (n=1)	Violin
F (n=4)	Fire	**N** (n=1)	Nail		
	Finger			**W** (n=6)	Wine
	Fox	**O** (n=1)	Ostrich		Windmill
	Fork				Watch
		P (n=13)	Pineapple		Window
G (n=7)	Golf		Pear		Whistle
	Garlic		Pipe		Worm
	Guitar		Pepper		
	Gate		Parrot	**X** (n=0)	-
	Goat		Pen		
	Goal		Piano	**Y** (n=1)	Yoghurt
	Ghost		Pencil		
			Peach	**Z** (n=1)	Zebra
H (n=7)	Ham		Peas		
	Heart		Pumpkin		
	Harp		P*		

* denotes family name: for reasons of confidentiality these have been omitted

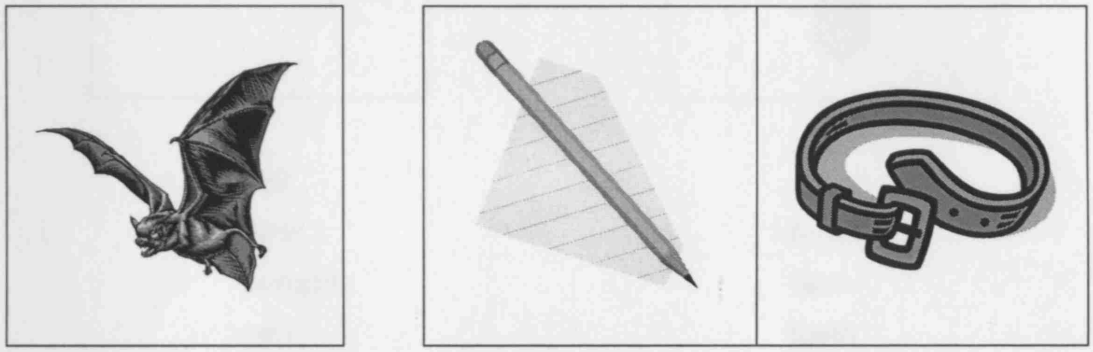
Appendix 6

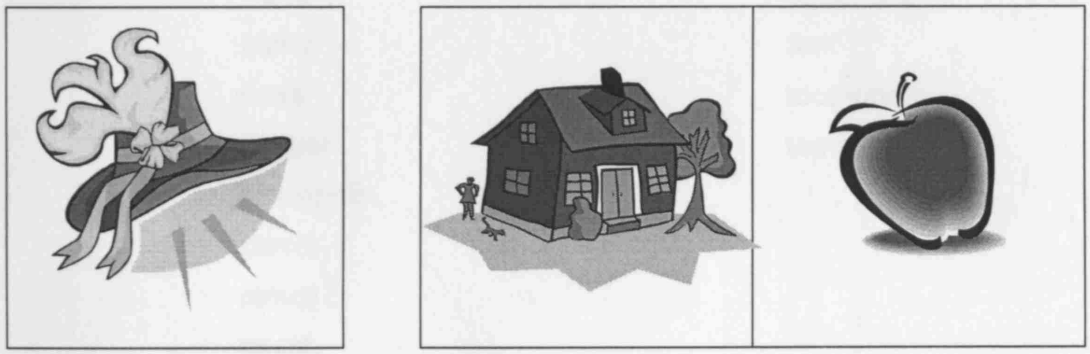
Examples of additional homework materials

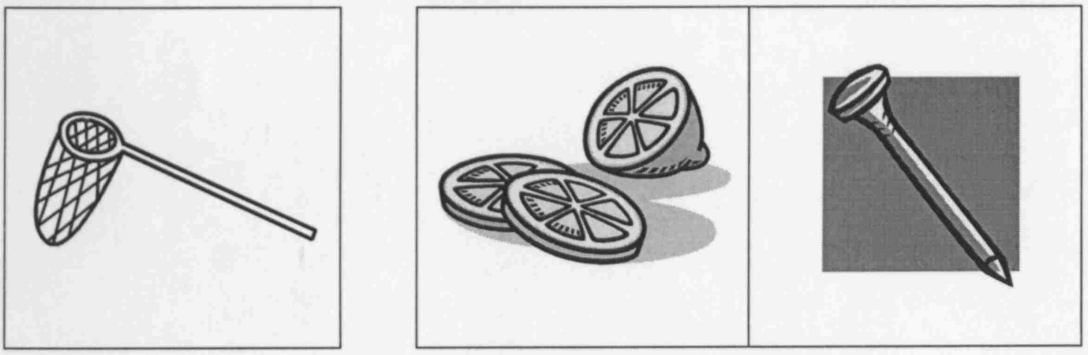
1 Picture matching task

Picture sheets containing one keyword picture and two (increasing to four) pictures from his therapy set were given to GK. His task was to select which therapy picture/s began with the same sound as the keyword picture.

Think of the first sound **Which picture name begins with the same sound?**

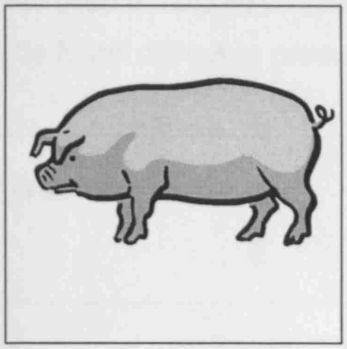






2 Listening list task, eg p/t

GK was asked to listen to a randomly presented list of words and match each one to one of two keyword pictures according to their initial sound.



/p/	/t/
pear	toilet
pumpkin	table
pen	teeth
pipe	torch
Paris	telephone
piano	tent
peas	toothbrush
pepper	tomato
pineapple	
parrot	
pencil	
peach	

Appendix 7

Listening task items: sessions and scores

The table below shows the pairs of phonemes which were focussed on in the listening tasks and GK's discrimination score for each therapy session. This task was used to help him focus on hearing the distinctions between sounds which he found difficult to produce.

Phoneme pairs	Session score (%)				
	6	7	8	9	10
b/f	92 (n=12)				
h/k	92 (n=13)				
r/p	85 (n=20)				
a/c	100 (n=13)				
j/m	92 (n=12)				
t/w	93 (n=14)				
p/l		100 (n=8)			
p/t		100 (n=8)	87.5 (n=8)	87.5 (n=8)	
t/k		100 (n=8)	100 (n=8)	100 (n=6)	
t/c		100 (n=8)	100 (n=7)	100 (n=8)	
t/h			100 (n=19)		
d/m			100 (n=13)		
p/k			100 (n=8)	100 (n=8)	
p/c			100 (n=8)	100 (n=8)	
p/b			80 (n=15)	85 (n=20)	86 (n=14)
t/d			65 (n=17)	82 (n=17)	85 (n=13)
c/f				100 (n=16)	
k/w				100 (n=11)	
g/l				100 (n=15)	
k/g				79 (n=19)	
c/g				85 (n=13)	95 (n=19)