# A Computer Supported Memory Aid for Copying Prescription Parameters into Medical Equipment based on Linguistic Phrases

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***Abstract*— Manually operated medical equipment, including drug infusion pumps, are often subject to input errors. Human operators copy data from a prescription into the relevant form field on the equipment panels. This process is error prone and time consuming. A computer supported memory aid is proposed where the user remembers phrases instead of value sequences. The proposed strategy speeds up the task of setting up medical equipment while reducing the chances of human errors.**

***Keywords-memory aid, digit input, medical user interface***

## I. INTRODUCTION

Medical equipment, in particular drug infusion pumps, may be operated by individuals who do not have a deep understanding about the meaning of the parameters that are input [1, 2]. It can be paramedics in ambulances, nurses in hospitals or even patients themselves in their own homes. Typically, a drug infusion pump is administered by copying the values from a prescription, written down or communicated in spoken form into the relevant input fields on the device. This process can lead to errors [3, 4, 5, 6] and the characteristics of digits in medical systems have been studied specifically [7, 8]. Errors can occur while reading [9], or listening, they can occur in the human memory system [10] and errors can occur during input [11, 12, 13, 14].

Reading sequences of digits is challenging, especially if the numbers are relatively similar, but yet not identical. This is especially so when the sequence of numbers have little or no apparent structure. Research shows that humans typically have a capacity to remember five items of relevant information in one go [15, 16]. The copying of longer sets of data therefore needs several read-memorize-input cycles. For each such cycle the copying may start at an incorrect location in the printed source. Moreover, for each cycle data may be input into an incorrect field on the device. This is because the eyes shift between the source text and the input field on the device for each cycle.

Errors can also occur during input. Text input studies often report error rates of about 5-10% [11] and there are no reason to believe that digit error rates are any smaller for medical devices although the input interface can affect the error rate. Errors can simply be caused by hitting the wrong keys. With medical equipment, the values can be either large or very small and so-called out of 10 errors can occur [17]. Out of 10 errors are caused by an incorrect positioning of the decimal point. Out of ten errors are severe as the resulting value becomes a ten-fold smaller or larger than intended.

The input mechanisms offered by medical equipment broadly fall into three categories, direct input, jog input and digit increment/decrement input. Direct input requires a numeric keypad where the values are input as a sequence of digits. Jog input require a jog wheel or up and down button where the digit is set by cycling up or down through the range of numbers. Digit Increment/decrement requires each digit to be assigned a separate digit up and down button and the input number is input by setting each digit accordingly.

The idea of manually setting up medical equipment may seem arcane with internet enabled devices. There are many technologies that enable remote operation of devices or computer assisted configuration such as the use of bar codes [18]. Therefore, the technique presented herein is intended as a supplement to, and not a replacement for, remote or direct setting of medical devices.

The method proposed extends previous work on the use of linguistic words to represent the various values [19]. Each parameter is associated unique word lists to ensure that each value is copied into the correct form field. The novel contribution in this work is that the word sequences are composed such that the resulting phrases constitute grammatically correct phrases that are easier to remember. An error detection mechanism is also illustrated.

## II. METHOD

### A. Value coding

General floating point data types can accommodate numbers of the form $X{\cdot}10^{Y}$, where $X$ often surpasses 10 digit precision and $Y$ are in the ranges extending beyond -10 to 10.

TABLE I. VALUE TO NOUN ASSIGNMENTS

| | Y=-3 | Y=-2 | Y=-1 | … | Y=3 |
|---|---|---|---|---|---|
| X=1 | ball | bat | bed | … | van |
| X=2 | apple | arm | banana | … | bird |
| … | … | … | … | … | |
| X=9 | advice | anger | answer | … | year |

TABLE II. ENTRIES IN EACH WORD CATEGORY.

| Category | Entries | Fields | Type of parameter |
|---|---|---|---|
| Nouns | 2,341 | 37 | compulsory/optional |
| Verbs | 1,050 | 16 | compulsory/optional |
| Adjectives | 1,100 | 17 | Optional |
| Prepositions | 82 | 1 | error correction |

Values used in drug infusion pumps typically are in the range of $10^3$ to $10^{-3}$. Common drug infusion parameters include concentration, titration limit, amount to infuse, rate of injection, vein open rate, loading dose, bolus dose to mention a few.

Often equipment specification states accuracies of ±12%. The accuracy and precision offered captured by computer data types therefore is much higher than what is actually required for most purposes. Thus, to capture most values relevant for such equipment one need a value in the form $X{\cdot}10^Y$ where $X$ is in the range 1 to 9 and $Y$ is in the range -3 to 3. It is assumed that most applications do not employ explicit negative numbers. This thus only represents $7 \times 9 = 63$ different values. These values are coded by arbitrarily assigning each value a unique linguistic word as illustrated in Table I.

Note that only high frequency words increase the chances that these are words known, and recognizable, to the users. Moreover, the words also are in the same category – in this case the values are assigned to nouns. For example, the value 0.002 equals $2{\cdot}10^{-3}$ where $X$=2 and $Y$=-3 matching the word *apple* in Table I. Similarly, the value 1,000 equals $1{\cdot}10^3$ where $X$=1 and $Y$=3 matching the word *van* in Table I.

In this case 1,000 is a round number that can probably remembered as one piece of information, while 0.002 is a more awkward number which probably requires two information pieces, that is, the position of the decimal point and the value. To remember the word *apple* is just one simple piece of information.

With double digit accuracy, that is $Y$ in the range of 1-19 one would need to represent 630 different values using 630 different words.

### B. *Value form-field assignments*

Errors occur if values are inserted into incorrect input fields. To overcome this problem the proposed coding ensures that the value will be automatically routed to the correct field independently of the order in which it is input. This is achieved by introducing different word sets, that is, one word set per form field.

The English language contains more than 100,000 words. However, many of the words are the same word in different grammatical form and some of the words are not frequently used and are thus unknown to most people. Assuming that the number of form fields are limited the number of high frequently words should be sufficient to cater for most needs.

High frequency word lists in different categories can form the basis for word sets as shown in Table II. For instance, there are more than 2,300 nouns, 1,050 verbs and 1,100 adjectives that together cover over 70 form fields which far exceed the needs of most equipment.

Some parameters are optional while others are compulsory. It is thus important to assign compulsory parameters as nouns and verbs to generate complete sentences, and assign optional parameters to adjectives as this will allow the phrases to appear more natural and grammatically correct.

### C. *Error detection*

Each word has an internal structure that prevents human error. Moreover, spelling error detection can be used to catch input errors [21].

Next, simple parameter instructions comprising one or two parameters do not need error detection to the same degree as longer parameter sequences. A simple parity-type error detection scheme is easily introduced by using an additional word [21]. For this purpose a preposition is suitable as prepositions can be inserted into most phrases with several clauses while maintaining grammatical correctness. By having a separate word class for the purpose of error detection means that error detection can be made optional. If employed error detection words can be detected dynamically during decoding.

Assume that each word class $W_i$ with a word representing number $N_i$ is assigned a randomly generated unique integer factor $R_i$ in the range of 1 to 81, the error detection code $C$ is calculated as

$$C = (N_1R_1 + N_2R_2 + .. + N_nR_n) \bmod 82 \quad (1)$$

The phrase is then assigned the $C$'th preposition in the list. Similarly at the decoding end the detection code is computed with the same integer factors and the result is compared to the index of the preposition. The multiplication factor adds robustness to the error detection.

The list of 88 prepositions helps capture 98% of all errors.

### D. *Grammatically correct phrases*

Previous computer assisted memory aids for digit copying tasks employed one word list for all digits. The resulting phrases could thus be hard to remember as they were not meaningful in terms of content or grammar. To ease the memory task the phrases should at least be grammatically correct. To compose grammatically correct phrases from the words representing the phrases a list of sentence template can be used such as the one listed in Table III.

The objective is not to create sentences that convey meaningful content, but rather generate grammatically correct sentences that are interesting, trigger the users' imagination and generates memorable images.

TABLE III. ENGLISH SENTENCE TEMPLATES

| Template | parameters |
|---|---|
| The+[noun]+[verb] | 2 |
| The+[noun]+[verb]+[noun] | 3 |
| The+[noun]+[verb]+[preposition]+the+[noun] | 3 |
| The+[adjective]+[noun]+[verb]+[preposition]+the+[noun] | 4 |
| The+[adjective]+[noun]+[verb]+[preposition]+the+[adjective]+[noun] | 4 |
| The+[adjective]+[noun]+and+[noun]+[verb]+[preposition]+the+[adjective]+[noun] | 6 |

To increase the readability of the phrases the determined article "the" can be inserted in front of nouns, several nouns can be combined with "and" and verbs in present or perfect tense will make most sentences seem more natural.

## III. EXAMPLES

Using the templates listed in Table III we could for instance code two parameters say 0.02 and 50 with the phrase "*The arm agreed*". A four parameter sequence 40, 0.02, 0.02 and 0.001 could be coded using the phrase "*The coal amused against the college*". Both phrases sound strange and have no meaning, but they generate some image in the readers head. It is highly likely that the user will be able to copy these phrases in one cycle.

With a more complex parameter set comprising six parameters and an error code, say 30, 0.02, 0.02, 1000, 50 and 0.001 could be coded as "*The fancy slope and t-shirt cycled between the shy greek*". This is indeed an odd sentence, but it is more likely that a user will be able to copy this sentence in one go than to copy the seven values in one go. In this case the boundary of copying five pieces of information exceeded. Note that words in these examples were chosen randomly from each word category.

## IV. LIMITATIONS AND FUTURE WORK

The strategy presented herein is accompanied by arguments supported by empirical results from the literature on the study of memory. However, the feasibility of the proposed strategy should be evaluated through a series of user tests to shed light on actual performance improvements and reduction in error rates. One approach is to devise digit coping tasks and corresponding phrase copying tasks, according to the practices commonly reported in the text entry literature, where the phrases are coded with the same information as the digits and observe timing and error characteristics. Moreover, as medical personnel often operate under stressful situations it is recommended to also design performance tests where stress is a built in factor.

Although the current study are intended as a memory aid for memorizing information for very short periods of time it could be interesting to explore traditional mnemonic devices such as the method of loci were a list of items are associated with a set of locations and the method of peg words where a list of words are associated with words that rhyme with the ordinal numbers.

Another issue is that an individual with advanced understanding of a field is better able to remember domain specific details than a novice as the he or she will be able to understand the relationship and connection between the various items as shown for remembering code [22]. In such cases is the mnemonic device an actual aid or nuisance.

It is estimated that approximately 10-15% of the population has dyslexia or dyscalculia. It would be interesting to compare the digit and word copying performance of users with dyslexia to see whether it is different to that of non-dyslexic users.

## V. SUMMARY

A computer assisted memory aid is proposed specifically tailored towards the task of remembering drug infusion pump prescriptions. The approach reduces the change of error with both linguistic and mathematical error detection mechanisms. Moreover, the approach holds potential for allowing users to remember more than the five information pieces that are often states as the limit. The method achieves this though the use of grammatically correct phrases. The strategy is easy to implement, but require the equipment to have alphanumeric text input facilities.

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TABLE IV. EXAMPLE PREPOSITIONS FOR ERROR CODES

| val | word | val | word | val | word | val | word | val | word | val | word | val | word | val | word |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10 | amid | 19 | behind | 28 | concerning | 37 | for | 46 | minus | 55 | out of | 64 | since | 73 | underneath |
| 11 | amidst | 20 | below | 29 | considering | 38 | from | 47 | near | 56 | outside | 65 | than | 74 | unlike |
| 12 | among | 21 | beneath | 30 | despite | 39 | in | 48 | next | 57 | over | 66 | through | 75 | until |
| 13 | anti | 22 | beside | 31 | down | 40 | in front of | 49 | of | 58 | past | 67 | till | 76 | up |
| 14 | around | 23 | besides | 32 | during | 41 | inside | 50 | off | 59 | per | 68 | times | 77 | upon |
| 15 | as | 24 | between | 33 | except | 42 | instead of | 51 | on | 60 | plus | 69 | to | 78 | versus |
| 16 | at | 25 | beyond | 34 | excepting | 43 | into | 52 | on top of | 61 | regarding | 70 | toward | 79 | via |
| 16 | atop | 26 | but | 35 | excluding | 44 | like | 53 | onto | 62 | round | 71 | towards | 80 | with |
| 18 | before | 27 | by | 36 | following | 45 | mid | 54 | opposite | 63 | save | 72 | under | 81 | within |
| | | | | | | | | | | | | | | 82 | without |

TABLE V. EXAMPLE ENGLISH NOUN PARAMETER TABLE

| | | Y | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | X | -3 | -2 | -1 | 0 | 1 | 2 | 3 |
| Parameter 1 | 1 | ball | bat | bed | aries | ash | atom | van |
| | 2 | apple | arm | banana | arithmetic | ashtray | attack | bird |
| | 3 | ant | apparel | archaeology | apparatus | asia | attempt | authorisation |
| | 4 | antarctica | appeal | archeology | armadillo | asparagus | attention | authority |
| | 5 | anteater | appendix | archer | armchair | asphalt | attic | authorization |
| | 6 | antelope | boy | architecture | armenian | asterisk | attraction | avenue |
| | 7 | anthony | appliance | area | army | astronomy | august | babies |
| | 8 | anthropology | approval | argentina | arrow | athlete | aunt | baboon |
| | 9 | advice | anger | answer | apartment | april | argument | year |
| Parameter 2 | 1 | aardvark | act | aquarius | aftershave | airport | alligator | australian |
| | 2 | abyssinian | action | arch | afterthought | airship | alloy | author |
| | 3 | accelerator | active | advantage | age | alarm | almanac | anatomy |
| | 4 | accordion | activity | advertisement | agenda | albatross | alphabet | anethesiologist |
| | 5 | account | actor | amount | agreement | alcohol | alto | amusement |
| | 6 | accountant | actress | afghanistan | air | algebra | aluminium | angle |
| | 7 | acknowledgment | adapter | africa | airbus | algeria | aluminum | angora |
| | 8 | acoustic | addition | aftermath | airmail | alibi | ambulance | animal |
| | 9 | acrylic | address | afternoon | airplane | alley | america | anime |
| Parameter 3 | 1 | back | bait | band | barbara | basket | battle | beat |
| | 2 | backbone | baker | bandana | barber | basketball | bay | beautician |
| | 3 | bacon | bakery | bangladesh | barge | bass | beach | beauty |
| | 4 | badge | balance | bangle | baritone | bassoon | bead | beaver |
| | 5 | badger | balinese | banjo | barometer | apology | beam | adult |
| | 6 | bag | ankle | bank | base | bath | bean | bedroom |
| | 7 | bagel | balloon | bankbook | baseball | bathroom | bear | bee |
| | 8 | bagpipe | bamboo | banker | basement | bathtub | beard | beech |
| | 9 | bail | adjustment | bar | basin | battery | beast | beef |
| Parameter 4 | 1 | beer | believe | bibliography | birth | blizzard | bobcat | bookcase |
| | 2 | beet | bell | bicycle | birthday | block | body | booklet |
| | 3 | beetle | belt | bike | bit | blood | bolt | boot |
| | 4 | beggar | bench | bill | bite | blouse | bomb | border |
| | 5 | beginner | bengal | billboard | black | blow | bomber | botany |
| | 6 | begonia | beret | biology | bladder | blowgun | bone | bottle |
| | 7 | behavior | berry | biplane | blade | blue | bongo | bottom |
| | 8 | belgian | bestseller | birch | blanket | board | bonsai | boundary |
| | 9 | belief | betty | bird | blinker | boat | book | bow |