Assistive Technologies 2

Human Computer Interaction Group (HCI)

Institute of Visual Computing & Human-Centered Technology,
TU Wien

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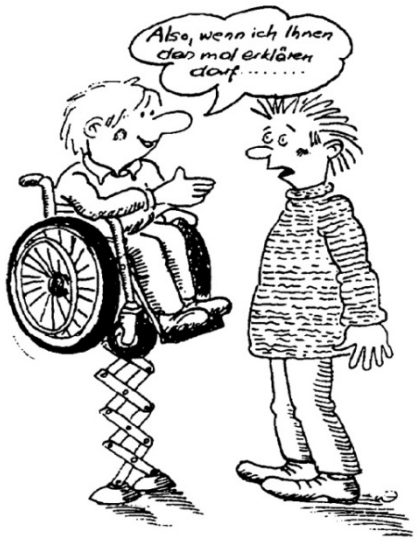


Content of Block 4

VC&HCT

4. Pictures and Symbol Languages
    - 4.4 Communication tables/boards
    - 4.5 Semantic Compaction
5. Alternative Communication
    - 5.1 Basics
    - 5.2 Speedup of Communication
    - 5.3 Text Prediction / Predictive Typing
6. Visual Communication
    - 6.1 History, Basics and Classification
    - 6.2 Lip Reading and Finger Alphabet/Finger Spelling

There are different methods

AAC method comparison:

	Literacy	Length of symbol combination	Number of symbols required	Symbol sequence length	Promotes message automaticity
Single Meaning Pictures	Not required	Short	Large	Short	No
Alphabet-Based Systems	Required	Long	Small	Long	Yes
Semantic Compaction	Not required	Short	Small	relatively short	Yes

Input via pictures or symbols - output via synthetic language

at the same time substitute for the voice

Communication via electronic picture / symbol board

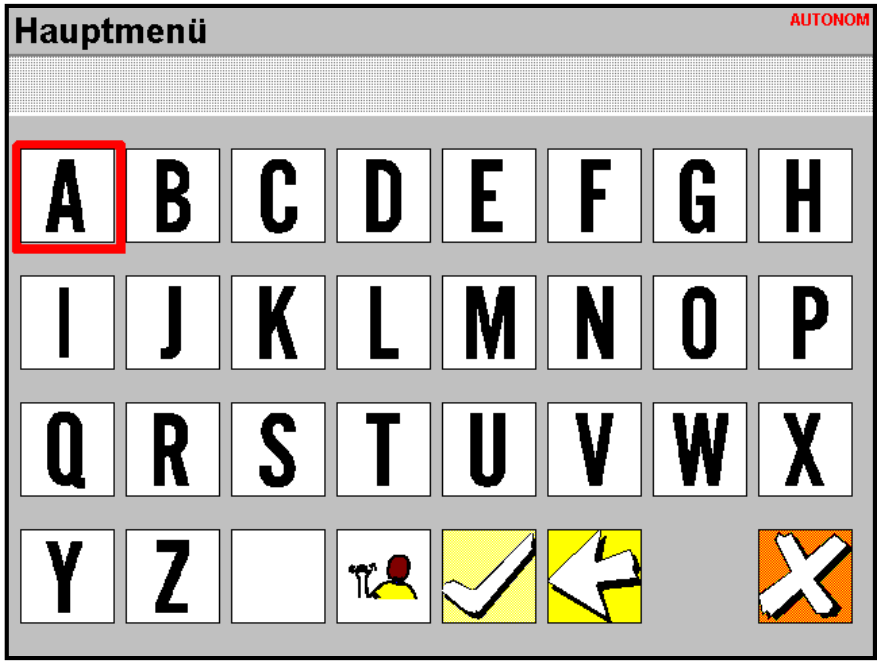
Static (graphic tablet) - - - - - - - - - - - Dynamic (touch screen)

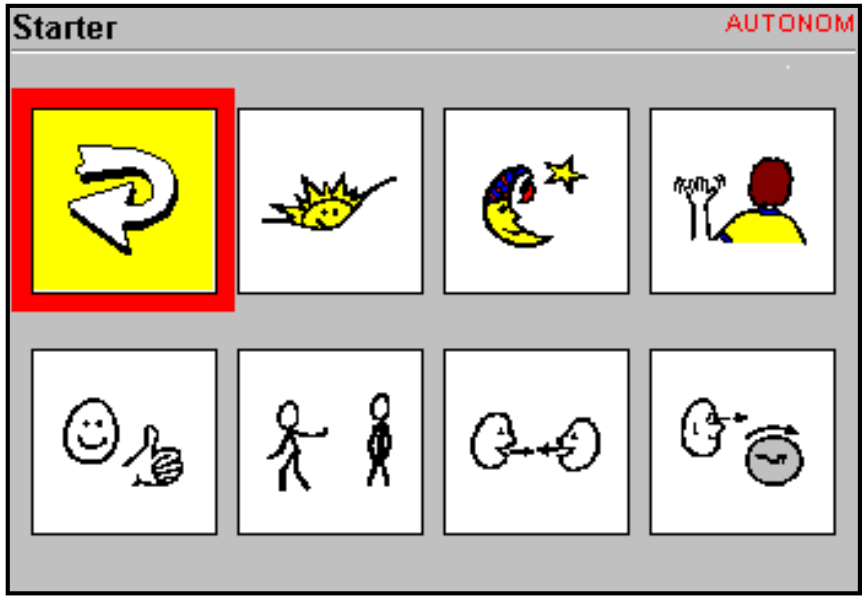
https://www.rehavista.de

Communication boards

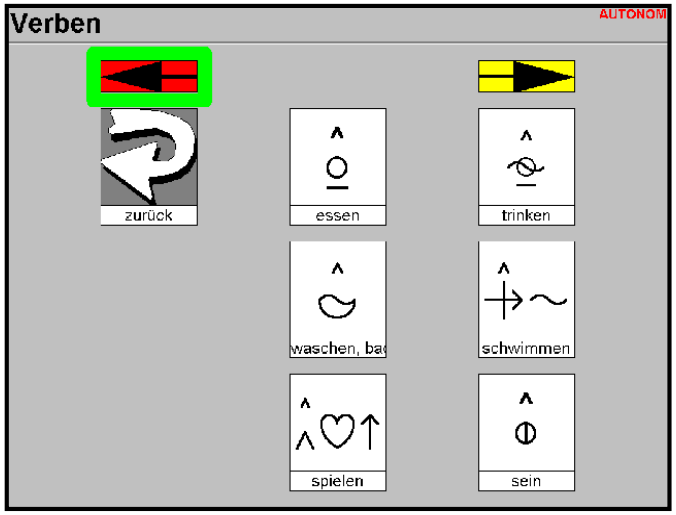
For digitized language total text duration from a few minutes to almost an hour.
Communication aids with "Semantic Compaction" (Minspeak) see 4.5, use speech output / full synthesis.
From a sequence of Bliss symbols grammatically correct sentences can be formed.
Dynamic displays (touch screen) or appropriately equipped notebook PCs.
Input also possible via scanning and single switch.

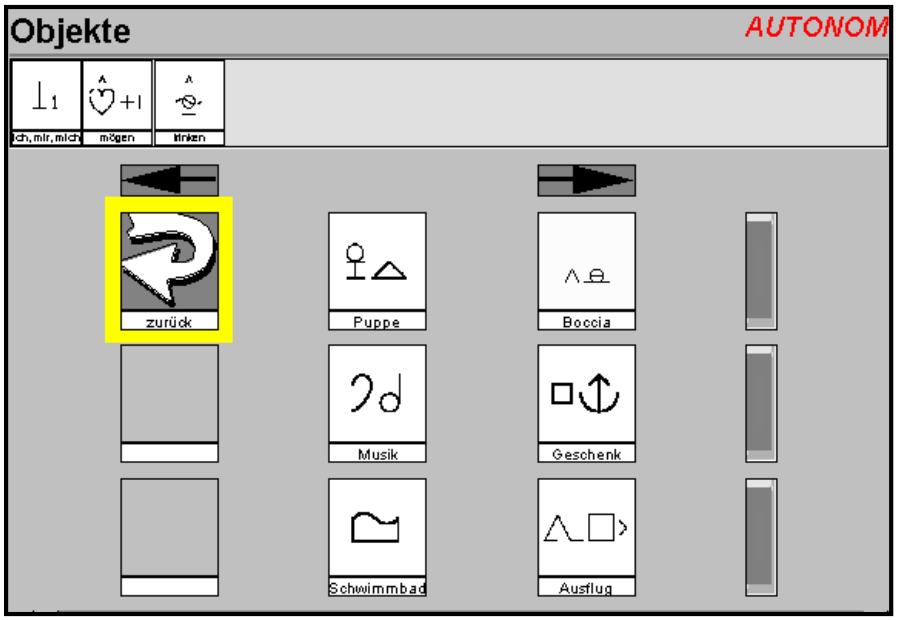
- Collect in edit line (ABC table top left) or
- Pronounce immediately after selection (symbol panel on the right)





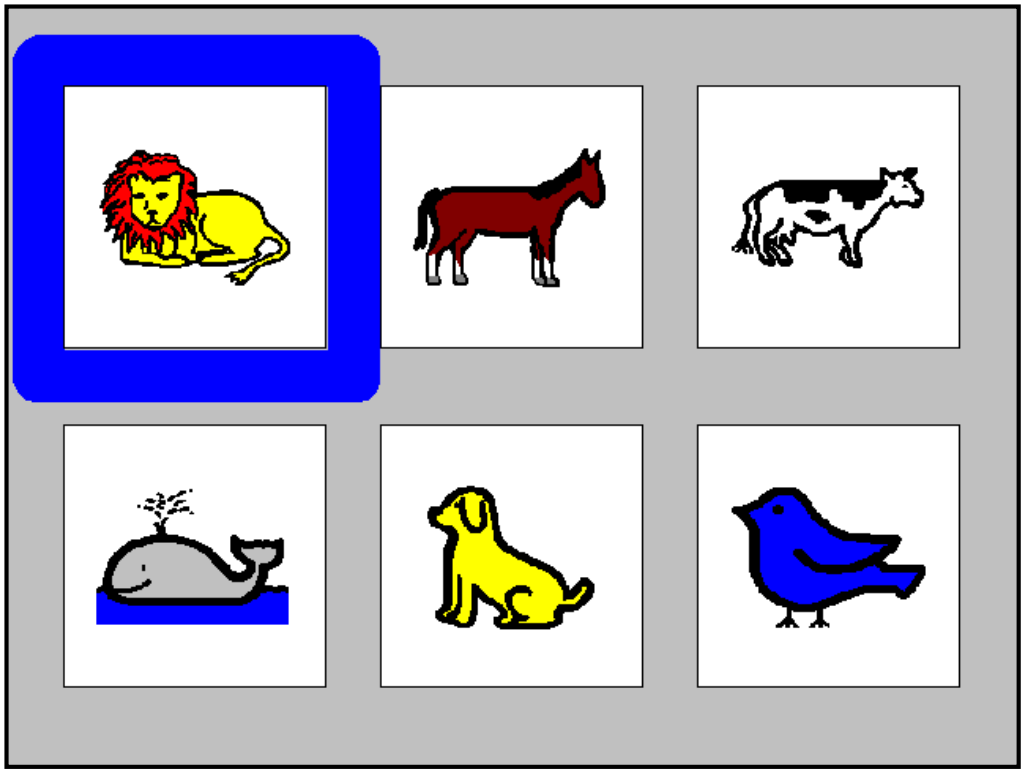
Editing line to compose a message
Speak in synthetic language or print





- Impairment of perception
- Manual scanning: 2 large buttons (YES = SELECT, NO = CONTINUE Scanning)
- as many senses as possible are addressed

- Each animal has an animal voice assigned
- Later on actions will be added in the environment



Example of communication speed

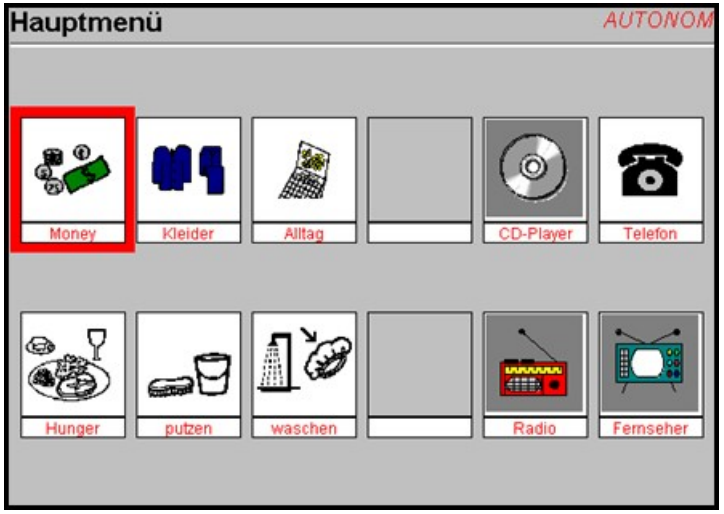
180 letter set (two lines of text) written with head or mouth stick
one stroke needs two seconds = 360 seconds, exactly 6 minutes

With text prediction may be shortened to 3 minutes
Non-disabled person (900 char/min): speaks only 12 seconds
=> Ratio 15: 1

Phrase catalog (picture communication) is fast but limited in the expression range

Technical Assistance System AUTONOM

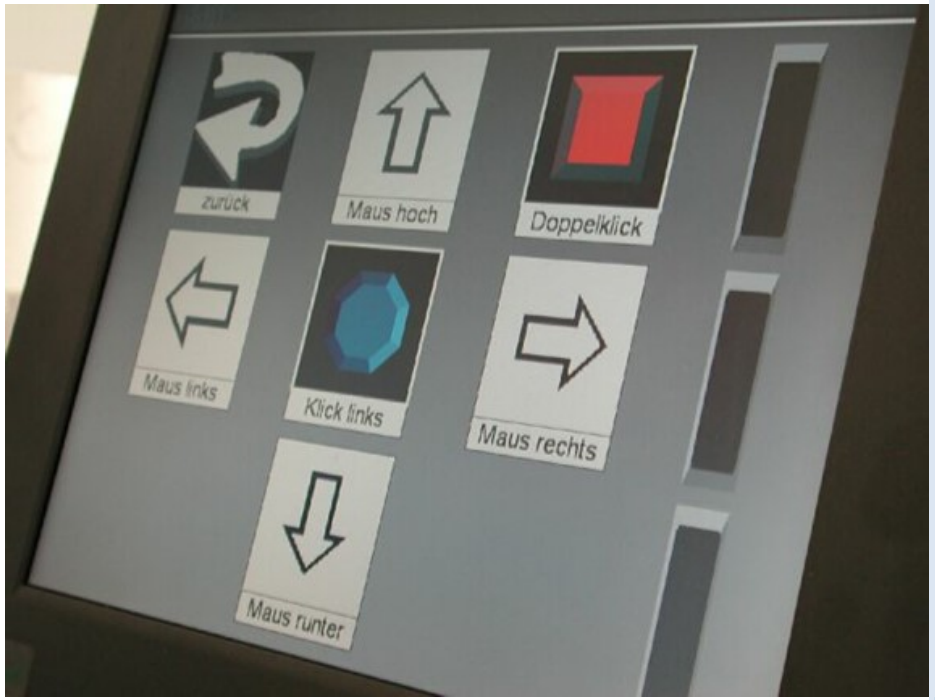
Input on PC via head stick + key mask
or via single button + scanning



- Communication with the personal assistants
- Environmental control: CD, telephone, video, radio, ...

User reports (German):
http://www.fortec.tuwien.ac.at/reha.d/projects/autonom/seminar/index.html
http://www.fortec.tuwien.ac.at/reha.d/projects/autonom/seminar/download/4-Hela.pdf

Technical Assistance system AUTONOM assists student of informatics at TU Wien



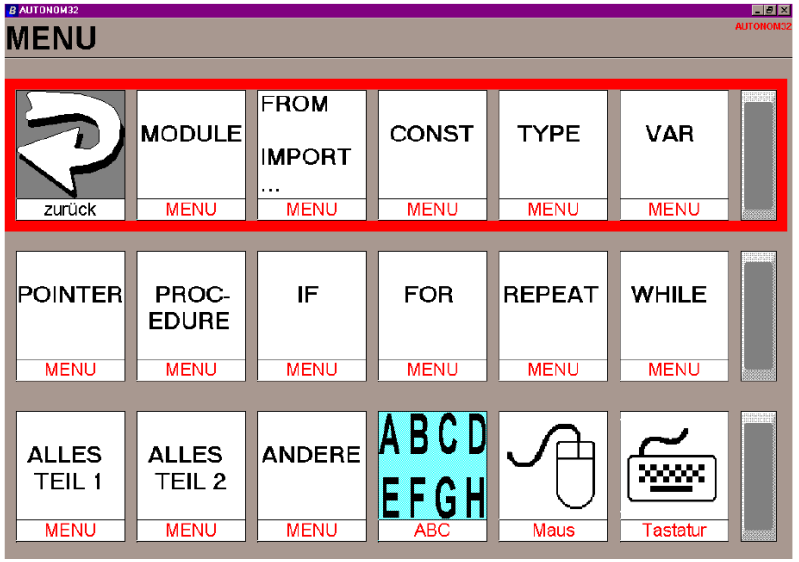
Control of the AUTONOM laptop via single button (left foot) and scanning.
AUTONOM emulates mouse and keyboard input for the desktop PC. On the desktop PC runs a software development environment with which the programming exercises are to be solved.
The configuration of the AUTONOM laptop is done by tutors according to the requirements of the exercises.

Mask for EPROG (Introduction to Programming)

"My tutors now had the task to adapt the notebook with the Autonom system to my needs, that is, to create masks for the respective lectures and exercises.

An essential point in the creation of the masks was, that for programming there are many recurring very long keywords, which should be able to be entered with as few as possible keystrokes. "

(Andreas Dendl, student of computer science at the Vienna University of Technology)



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Semantic Compaction

Method using pictorial language to formulate any sentences.
Strategy such as in Chinese

Typical: 50 pictorial symbols, sentence formation consisting of a sequence of only 4 symbols
Theoretically 50^4 = 6,250,000 sentences possible
Practically not usable to this extent (not memorizable)

Semantic Compaction ... (Definition of B. Baker)

... is the systematic use of secondary iconicity to reduce the number of symbols in a conceptionally-based selection set for the representation of natural language.

(Bruce Baker, 1994)

Explanation of the terms: "Selection set"

Total amount of items available for selection in a system.

Example 1: Morse code: 3 symbols: point, dash and pause.
For 26 letters sequences of up to 4 elements.

Example 2: Chinese: several thousand symbols

Semantic Compaction: Selection sets: 50 to 100 symbols
Several thousand terms representable
Strings of maximum four characters.

Explanation of terms: "natural language"

Languages like German, English, French etc.

Natural languages consist of semantic units (lexemes) linked by syntax

Explanation of terms: "Based on concepts" (Conceptionally based):

Language is based either on ...

- Concepts: e.g. hieroglyphs began in their original form as a collection of images to express certain thoughts and things
- or phonetics: As the need for communication increased, more and more phonetic elements were added

"Our" languages are completely phonetics based.

Explanation of terms: "secondary image meaning"

Primary image meaning is the "superficial" image meaning. The picture means exactly the represented object, snowflake means snowflake.
Secondary meaning: "white", "cold", "winter" etc.

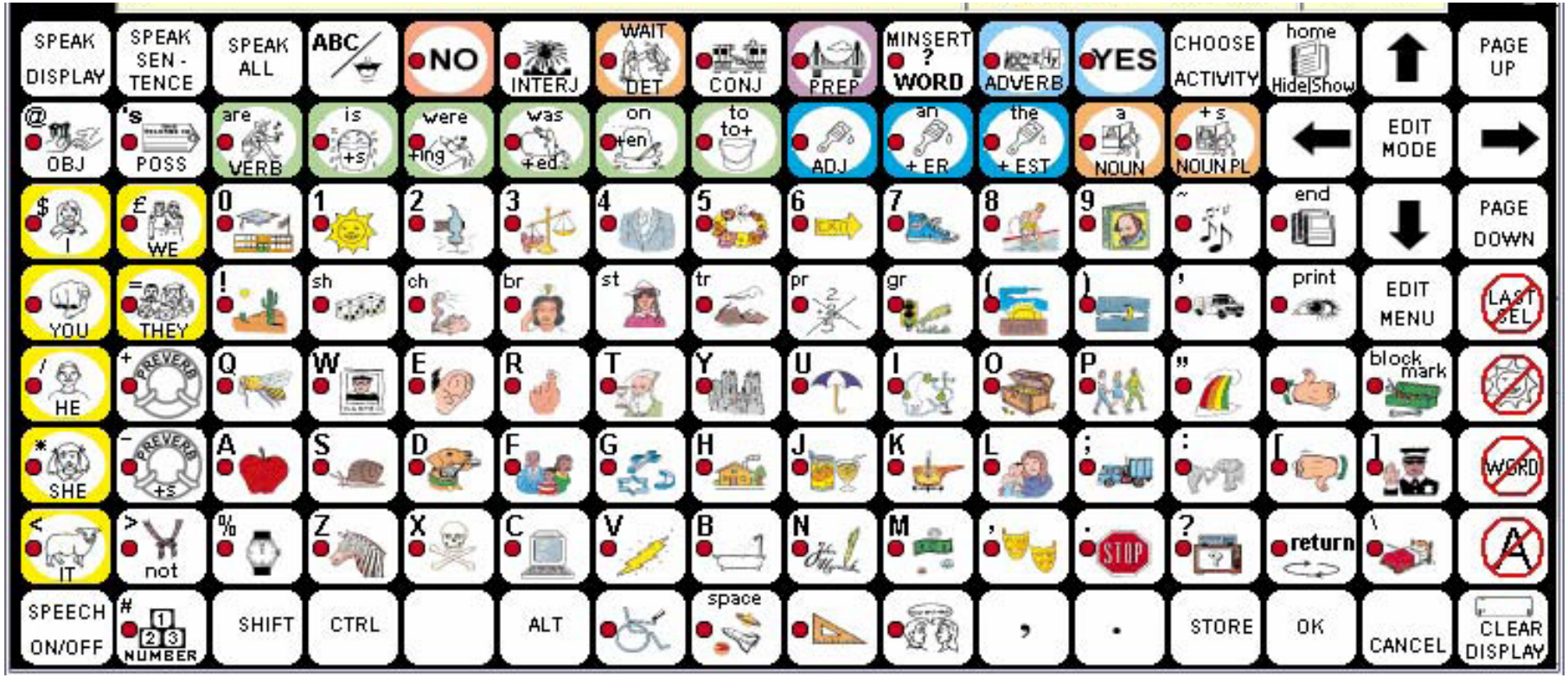
Ambiguous symbols not only express the object shown on top.
Associated concepts are added:
"what do you do with it?", "what belongs to it?", "where does that happen?", "what color, size, shape does that have?"

Examples

BED + NOUN key = furniture
BED + VERB key = sleep
BED + ADJECTIVE key = tired

Clear patterns used for organizing vocabulary: E.g. verb is always 1 or 2 icons, followed by the VERB key.

https://minspeak.com/about/


SPEAK DISPLAY
SPEAK SEN - TENCE
SPEAK ALL
ABC
NO
INTERJ
WAIT
DET
CONJ
PREP
INSERT ? WORD
ADVERB
YES
CHOOSE ACTIVITY
home
Hide|Show
PAGE UP
OBJ
POSS
are
VERB
is
+s
were
+ing
was
+ed
on
+en
to
to+
ADJ
an
+ ER
the
+ EST
a
NOUN
+ s
NOUN PL
EDIT MODE
I
WE
end
PAGE DOWN
YOU
THEY
sh
ch
br
st
tr
pr
gr
print
EDIT MENU
LAST SEL
HE
block
mark
SHE
WORD
IT
not
STOP
return
SPEECH ON/OFF
NUMBER
SHIFT
CTRL
ALT
space
STORE
OK
CANCEL
CLEAR DISPLAY


NO
INTERJ
WAIT
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CONJ
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O
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MORE
WIPE
SPEAK
DEL WORD
TO
PRONOUNS
A
+ S
SPELL
VERBS
NOUNS
POSS VERB
NUMBERS
PAST VERB
+ ING
SENTENCES
OPPOSITES
DRINKS
'I'+ VERB
YOU+VERB
FOOD
BODY
PHONE
'TH' WORDS
PREP/CONJ
LITTLE WOR
ADJECTIVES
HEALTH
TIME
NEGATIVES
MUSIC
PLACES
WEATHER
CLOTHES
COLOURS
HYGIENE
SOCIAL
JOBS
FAMILY
TRANSPORT
ROOMS
TV
DATES
SCHOOL
QUESTIONS
I like
'I'+ VER
I like
to go
TO
to go
home
PLACES
home

Target user groups are people with…

…with speech impairments,
…motor impairments,
…learning disabilities

Advantages
Only a small number of icons to be learned (40 – 80)
Icons on the display stay in a fixed location
Patterns applied to say a word can be used when learning to say new words

Commercial Product

Semantic Compaction used since 1980s, commercially available under brand name "Minspeak ®“ (Prentke Romich, Inc.) for PC and various communication aids (e.g. Touch Talker, Light Talker, Intro Talker, Liberator, Alpha Talker, Delta Talker)

https://minspeak.com/

Video example: Ellen uses input board with single button

https://www.youtube.com/watch?v=fAdEOXD9Tvk&feature=youtu.be

Duration: 5 Minutes

Basics, problems

With each type of communication, the time needed (the communication rate, the bandwidth) plays a crucial role.

Alternative communication can replace the function (lack of speech or voice) but is often decidedly slower.

Disabilities that have a negative effect on voice and / or language are often associated with motor disabilities => slow input on keyboards etc.

Specification of the communication speed

Usually stated in words / minute.
When converting to letters or strokes / minutes, consider the following:
The language used
The kind / type or content of the communication.

Specification of the communication speed

Average word lengths:
English: 4.7 letters / word
German: 5.3 letters / word.

Differences according to the type of text:
German fairy tale: 4.5 letters / word
German press release: 6.3 letters / word.

The following space (which also requires a stop) is not counted.

Typical communication speeds

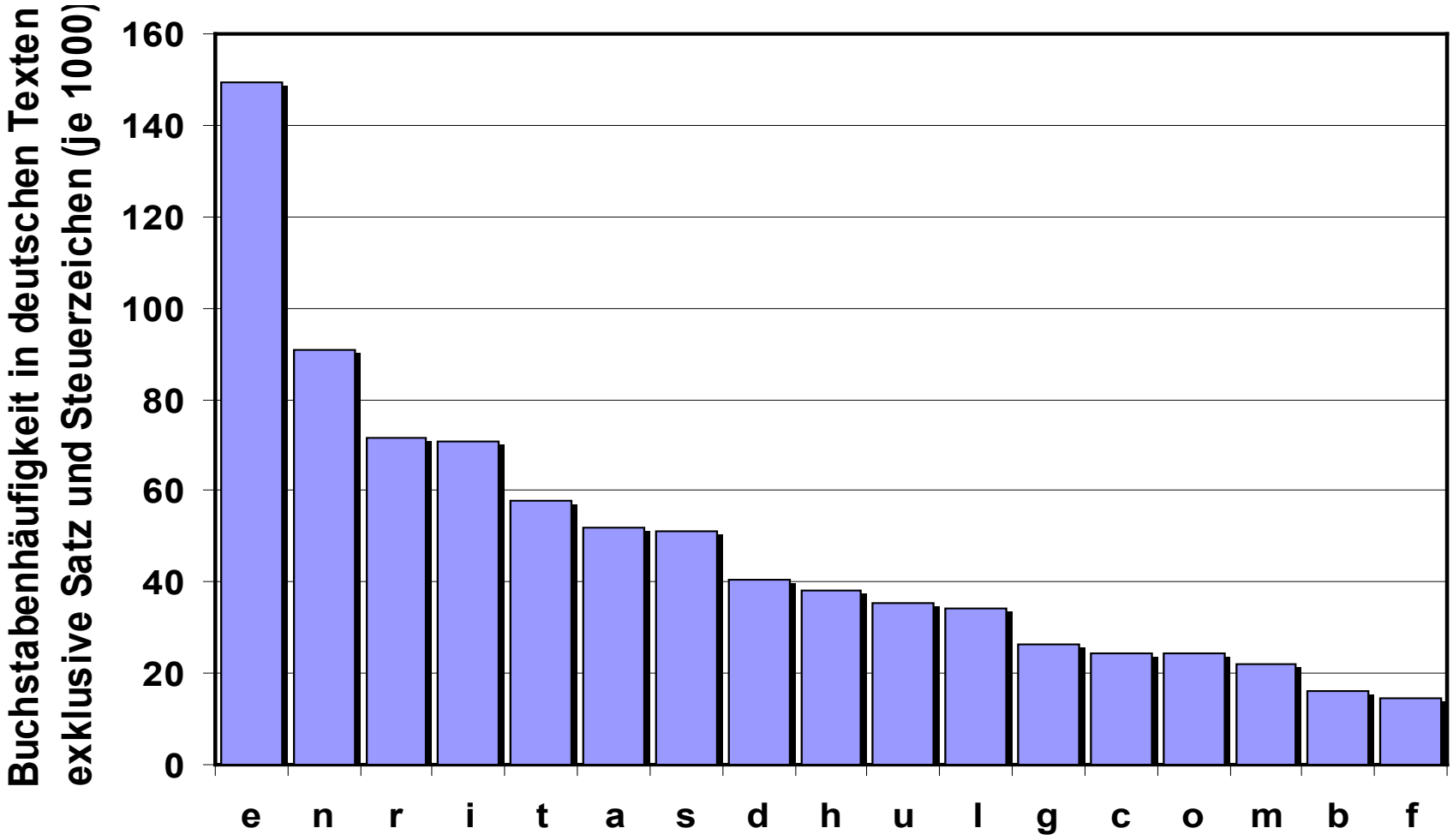
Method of Communication	Letters / min
Spoken language	800 to 900
Non disabled writer on keyboard	150 to 300
Keyboard input with mouth stick	75 to 120
Input with single switch and scanning	3 to 10

Arrangement of the letters during scanning:

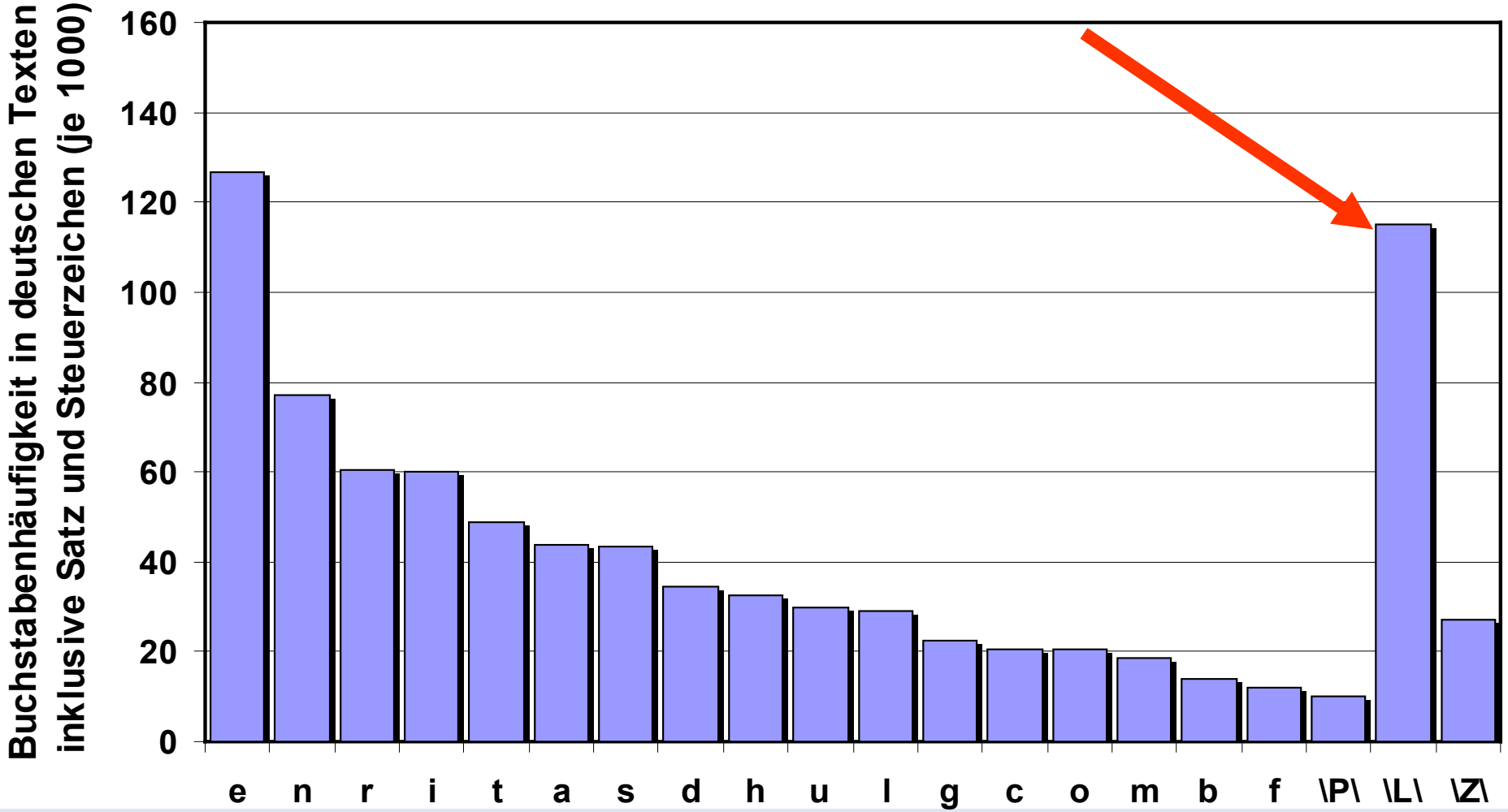
Alphabetical arrangement of the letters
Loss of time through long scanning paths

Sort by character frequency
Frequency or probability of occurrence
Put frequent letters at the beginning
Advantage: time savings
Disadvantage: needs getting used to

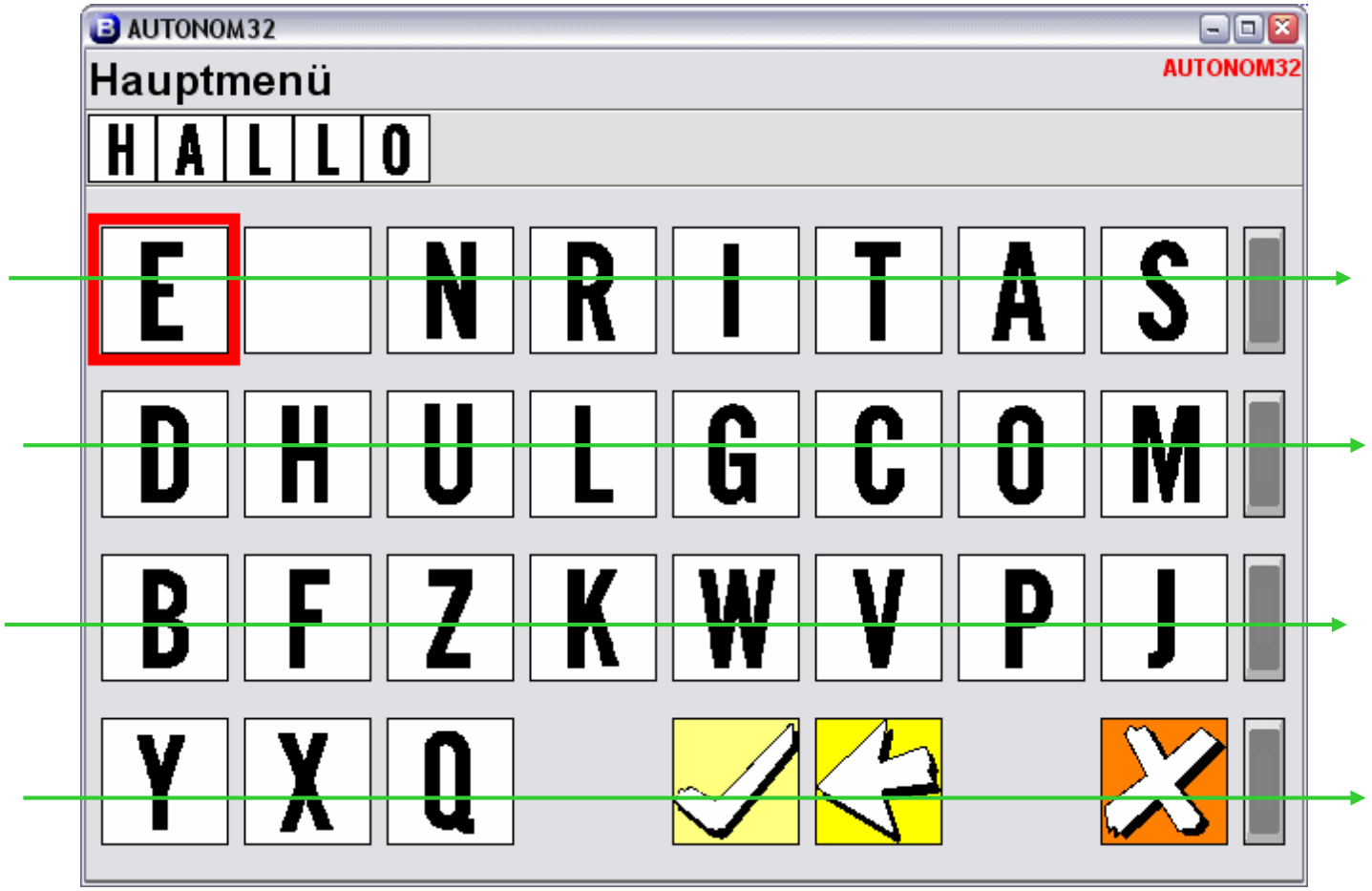
Letter frequency (German) **w/o** special characters per 1000



Letter frequency (German) **with** special characters per 1000 (\P: dot, \L: space, \Z: line feed)



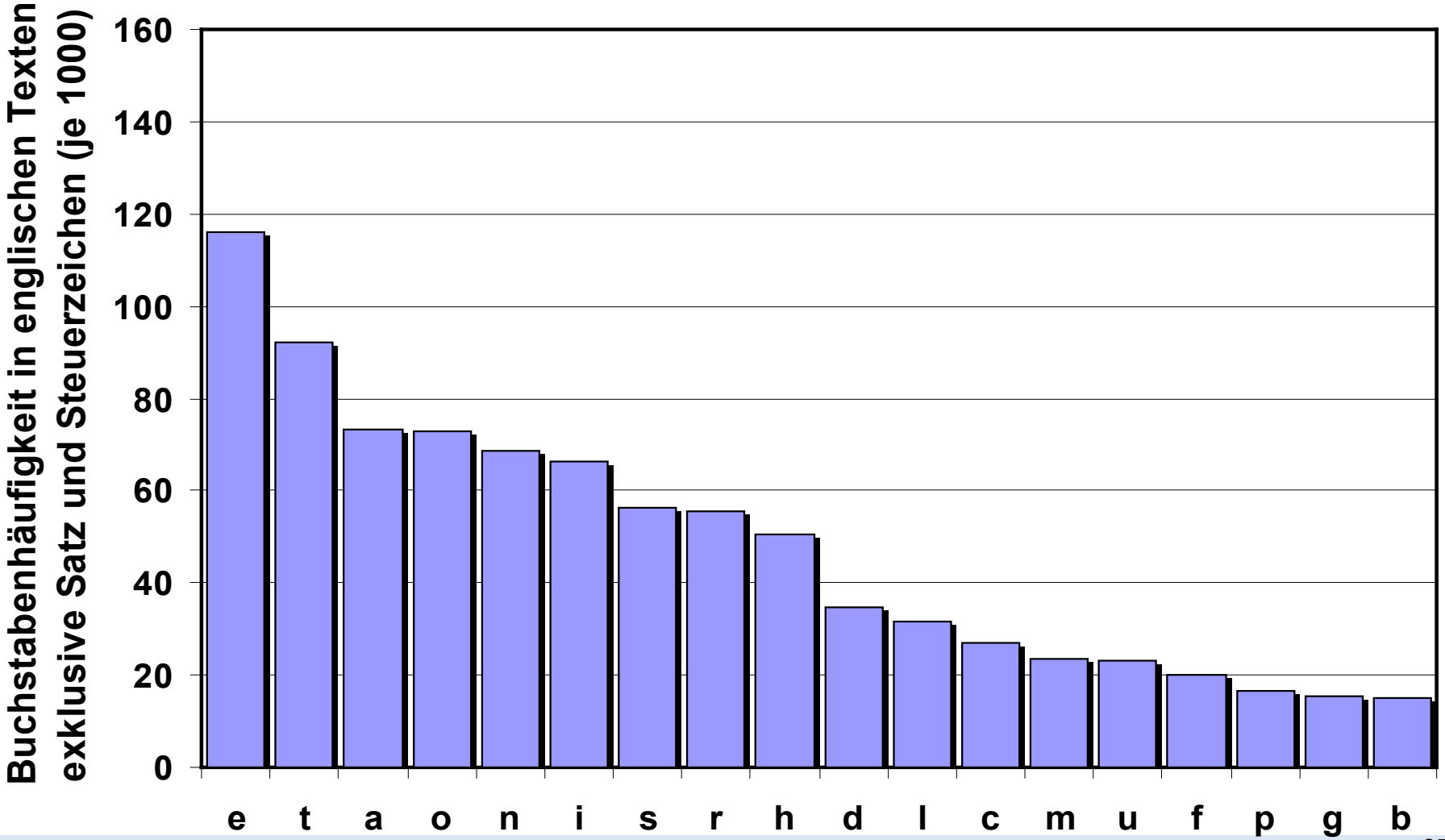
Optimized arrangement by frequency for linear scanning



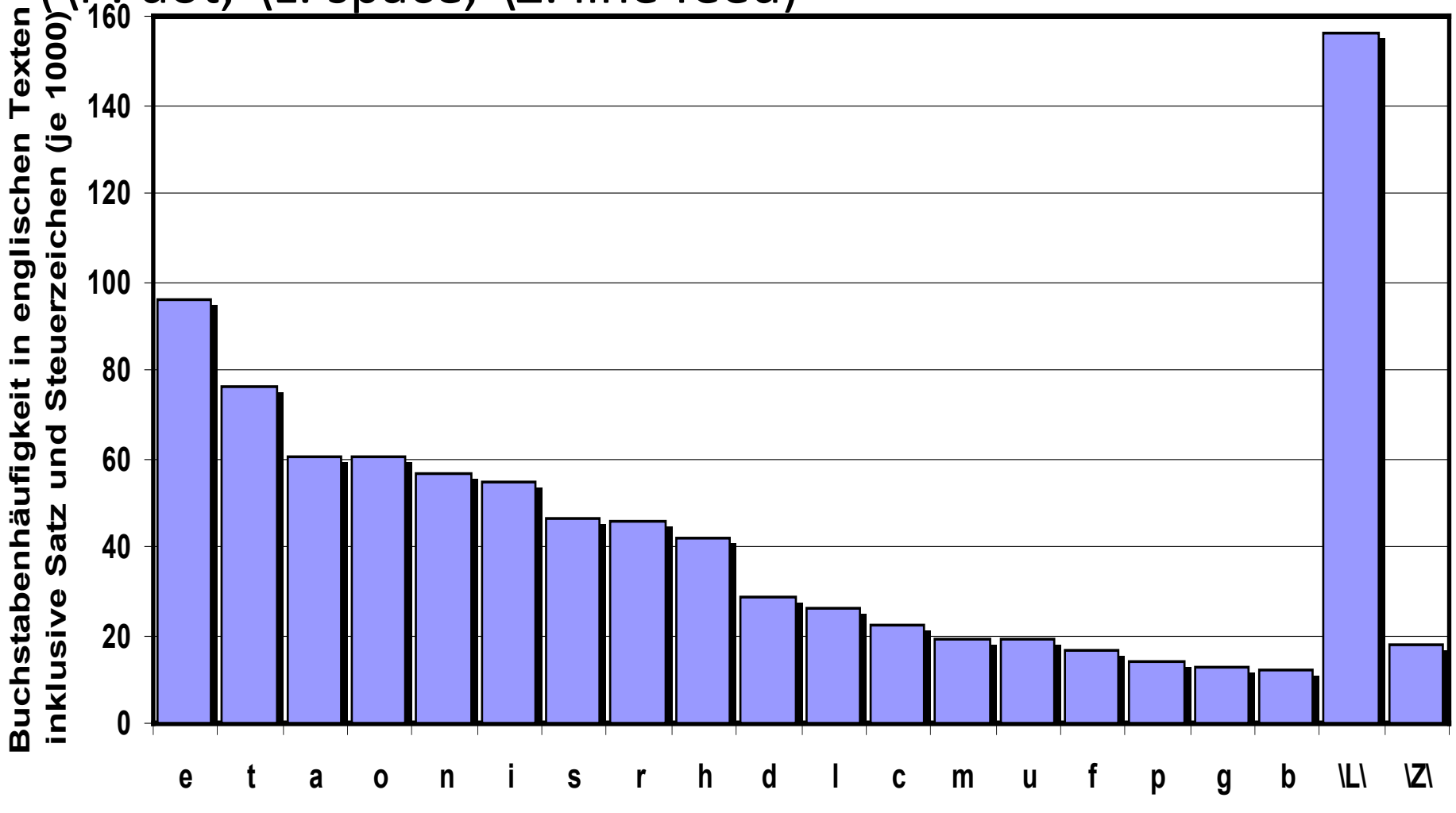
Optimized arrangement for row-column scanning

	1	2	3	4	5	6
1	E	LZ	R	A	U	O
2	N	I	S	L	M	.
3	T	D	CR	B	K	Ü
4	H	G	F	W	Ä	ß
5	C	Z	V	Ö	Y	Q
6	,	P	J	X	ZI	DE

Letter frequency (English) **w/o** special characters per 1000



Letter frequency (English) **with** special characters per 1000 (\P: dot, \L: space, \Z: line feed)



Each language contains a high degree of redundancy

It can therefore be attempted to generate the same information with fewer letters (keystrokes)

Especially for very slow writing people this brings an advantage

Abbreviations

Using abbreviations is technically simple and effective.
In case of Braille shorthand e.g. up to 30% saving on characters / keystrokes.
However, complicated rules and high performance required.

The reconstruction of a text from abbreviations is called abbreviation expansion.

Phrase Catalogs

In everyday life, a high degree of recurring phrases occurs.
Greetings, wishes for food, drink, help

Phrases in an electronic catalog that are addressed by shortcuts or symbols (on keys)
Problem with large catalogs: Remember the abbreviations or symbols.
Hierarchical-dynamic management of the icons on the screen
Increasing time required for navigation and selection!

Always limited to previously prepared context.

Text prediction

If interpersonal communication is done via an alphabet board, the other party will try to guess the rest after the first few letters of a word.

From the context can be concluded on the further course

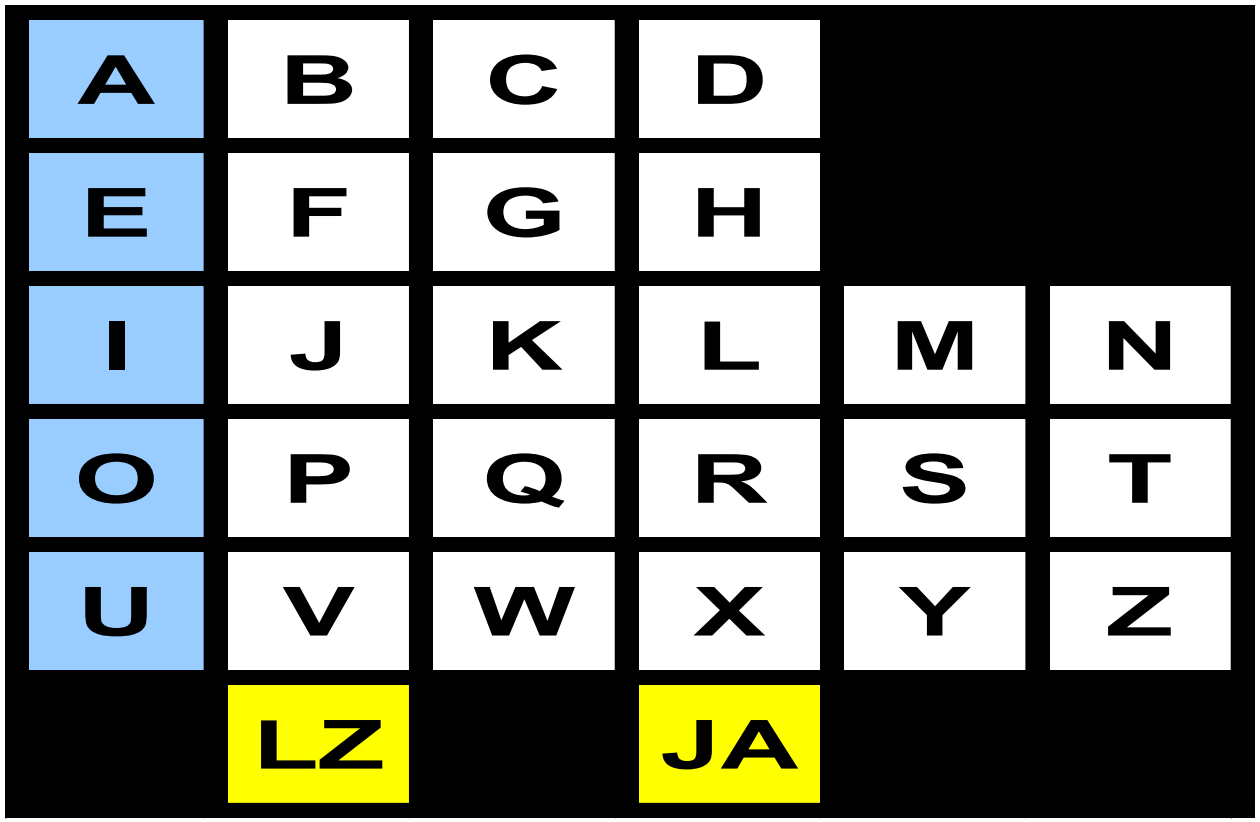
Up to 60% of keystrokes can be saved.

Experiment: Using an alphabet board

Definition of a coherent text, approx. 100 characters long
Slow pointing to the letters
Another person who does not know the text tries to guess the sequel.

Confirmation with "YES", if correct, continue writing if wrong.
Evaluation of the number of “keystrokes" with and without prediction.

Alphabet board



Text prediction with the computer

stored vocabulary
Suggestions for completing the word
“word completion"

First keystroke: k

Input	Prediction	
k	1	kann
	2	kein
	3	klein
	4	komme
	5	kommen

Second keystroke: o

Input	Prediction	
ko	1	komme
	2	kommen
	3	kommst
	4	komisch
	5	konform

Fifth keystroke: u ... and selection 5

Input	Prediction	
kommu	1	kommunal
	2	kommunale
	3	kommunales
	4	kommunaler
	5	kommunizieren

kommu5 = 6 keystrokes
created = 14 letters

KSR = 57%

Savings on keystrokes

Keystroke Saving Rate (KSR)

$$KSR\,[\%] = 100 \cdot k_{sav} = \frac{n_{st} - n_p}{n_{st}} = 1 - \frac{n_p}{n_{st}}$$

k_{sav} = Savings factor

n_{st} = Number of stops with conventional input

n_p = Number of stops with predictive input (letters + selection)

Assumptions for maximum attainable KSR

Every word searched for is already in the selection list before the first letter is entered.
Each word generated with a single stop

$$k_{sav1} = 1 - \frac{1}{l_{øw} + 1}$$

- $(l_{øw}+1)$ is the average word length plus trailing space
- for German language $l_{øw}$ is usually 5.3 letters / word

This results in a theoretical limit of :

$$k_{sav1} = 1 - \frac{1}{5{,}3 + 1} = 0{,}84$$

- But realistic are between 2 and 3 stops

$$k_{sav2} = 1 - \frac{2}{5{,}3 + 1} = 0{,}68$$

$$k_{sav3} = 1 - \frac{3}{5{,}3 + 1} = 0{,}52$$

Calculating the benefits of text prediction

Let **k** be the writing speed (stops / sec)
Let **B** be the number of letters in a text
Let **W** be the number of words (usually equal to the number of spaces plus the number of paragraphs)
Let **A** be the number of strokes to produce this text on a keyboard, where A = B + W.
Tk Total time for conventional text input

$$T_k = \frac{B + W}{k} = \frac{A}{k} \ [\text{sec}]$$

Calculating the benefits of text prediction

Any savings on strokes is time-saving
Writing with word prediction also takes time for
 Change of view from the keyboard to the screen and back
 Search the suggestion list
We call this extra time for making the right decision: **ts** (selection time [sec]).
Time required for the production of a text of length A: **Tp** (total time for text input with prediction)

Calculating the benefits of text prediction

This results in:

$$T_p = \frac{(1 - k_{saving}) \cdot A}{k} + (1 - k_{saving}) \cdot A \cdot t_s$$

Shortening by the time savings because of the KSR

Slowdown by selection times

Calculation of marginal utility k_{savg}

- Writing speed ***k***
- Selection time $\boldsymbol{t_s}$

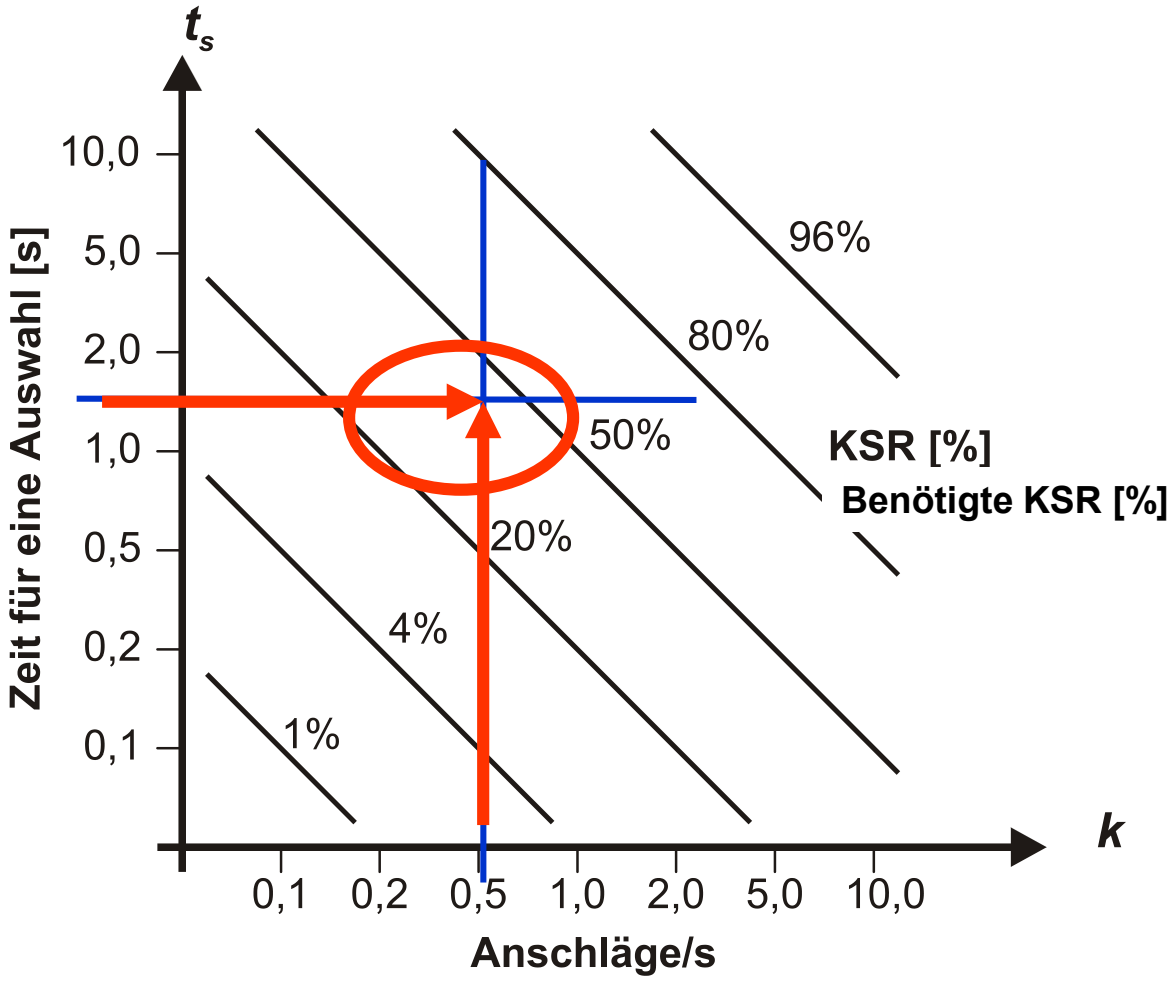
$$T_k = T_p$$

$$\frac{A}{k} = \frac{(1-k_{savg})\cdot A}{k} + (1-k_{savg})\cdot A\cdot t_s$$

$$k_{savg} = \frac{k\,t_s}{k\,t_s + 1}$$

Marginal utility shown graphically

A disabled person is able to produce a stroke every two seconds on average. The time it takes to make the selection from the list is 1.5 seconds. The intersection is slightly below the line for KSR 50% (exactly at 43%). That is, any text prediction that is capable of saving more than 43% of strokes is a time advantage to that person.



Alternative input strategy

Make suggestions only after several strokes

Assumption: KSR (normal) = 42%

KSR decreases, but search times also decrease

Strategy	*Lookups/char*	KSR [%]
Look up immediately	0,476	42
Look up after 1 strokes	0,236	38
Look up after 2 strokes	0,210	30
Look up after 3 strokes	0,114	21
Look up after 4 strokes	0,057	17

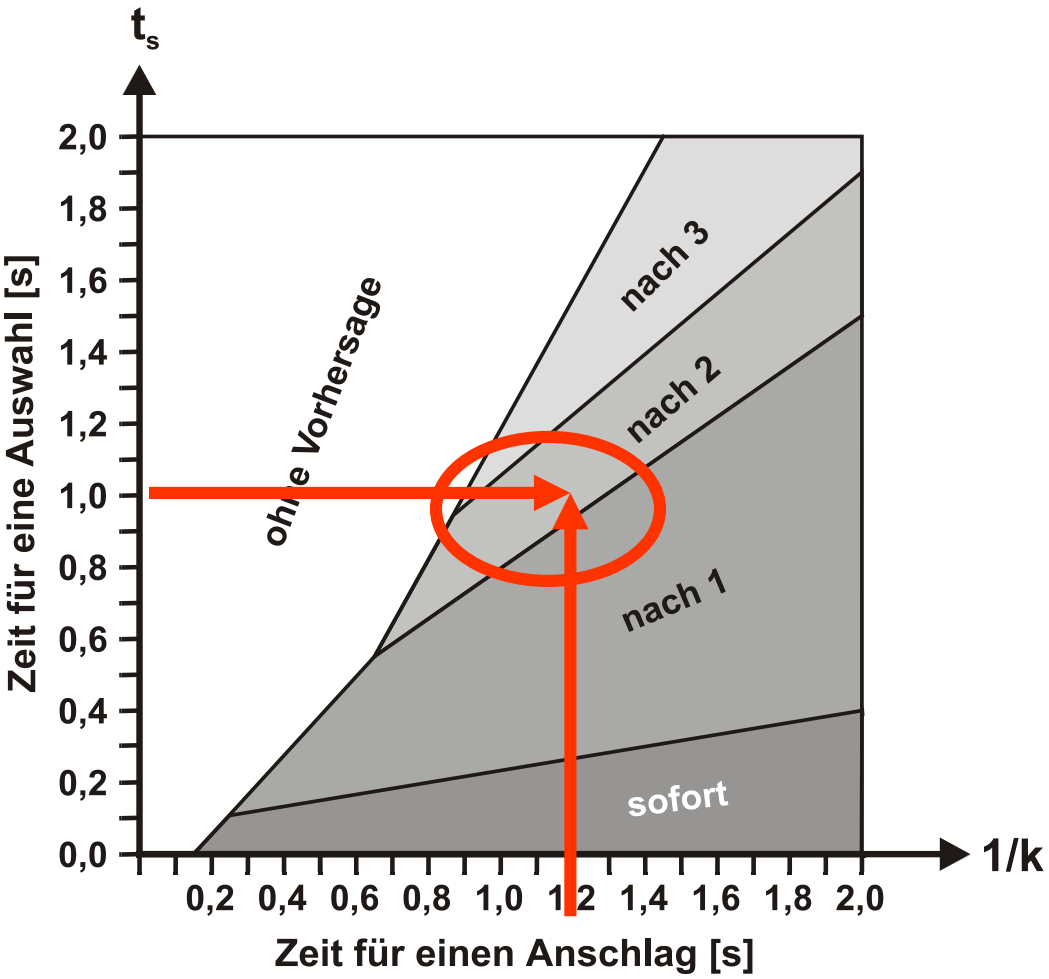
Horstmann-Koester, 1995

Optimization strategy: suggestions only after several strokes

The later the search of the list starts, the lower the number of searches per produced letter on the one hand, and on the other hand the lower the KSR.

If the profit from fewer searches is compared to the loss at lower KSRs, the correlation shown in the figure results.

For a given combination of k and ts, the diagram shows the most favorable number of stops after the first proposals are presented for selection.



Horstmann-Koester, 1995

Practical challenges

Necessary to read suggestion lists and at same time do not forget what should actually be said.
This can be problematic for some users with disability.

Saved key strokes are not the only criterion.
Is there an increase in communication speed?
Or a reduction of the effort associated with the writing?

In many cases, despite saved key strokes, the desired acceleration effect does not occur.

Additional benefits with text prediction

even if no direct time savings can be achieved -
For individuals with typing or spelling problems (dyslexia, dyslexia) or with difficulty finding words:

It's easier to pick the right word from a list of suggested words than to compose a word of letters yourself.

Increase in efficiency (1)

Prefer long words
Do not re-propose rejected words
Optimization of the length of the suggestion list
Adapted or adaptive vocabulary with appropriate size
Consideration of the relative frequencies (word frequencies, "frequency")
Considering the topicality of a word ("recency")

Increase in efficiency (2)

Separate treatment of word stem and ending.

Especially good for heavily inflected languages

1	forschen
2	forsche
3	forschst
4	forscht
5	forschte
6	forschtest
7	forschten
8	forschtet
9	forschend
10	forschende
11	forschender
12	forschendes
13	forschendem
14	forschenden
15	forschet

The problems word prediction systems have with morphology is extensive even in English. In French or German, morphological variations cover the screen in a word prediction system like fog on a misty night. *Bruce Baker*

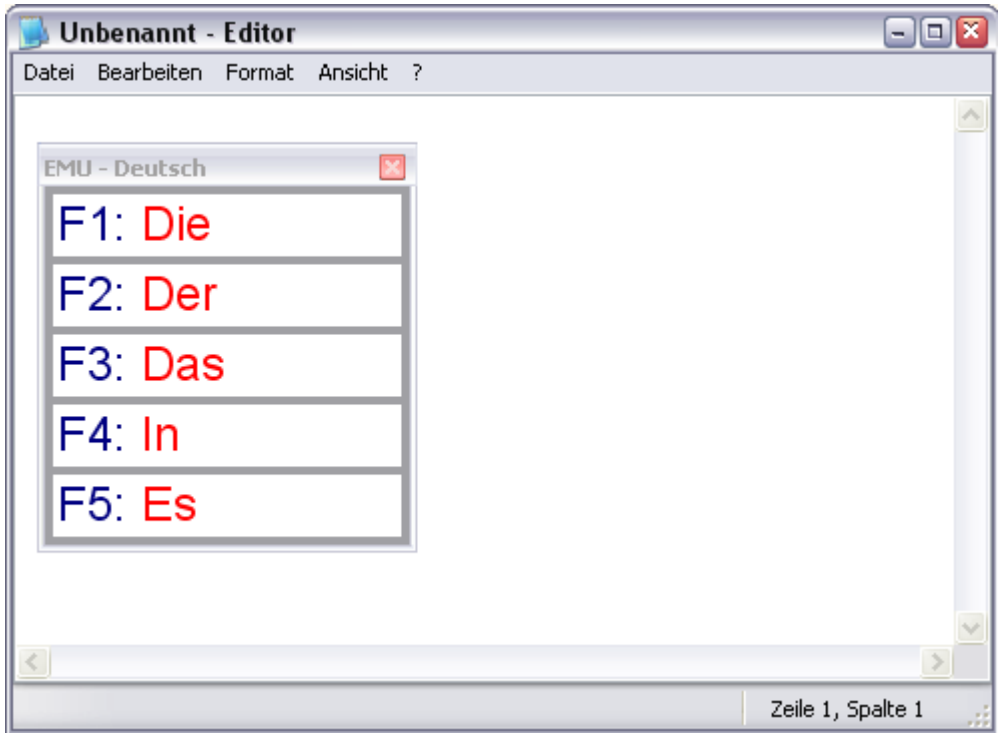
Increase in efficiency (3)

Inclusion of grammatical and syntactic rules
in the vocabulary each entry has corresponding grammatical markings (tags)

Selection is done taking into account the grammar
Suggestions list therefore contains only possible words
Inclusion of semantic relationships
Suggestions list is based on the thematic context
Use of methods of artificial intelligence and neural networks

Sentence to be written: Heute ist ein schöner Tag (see demo video)

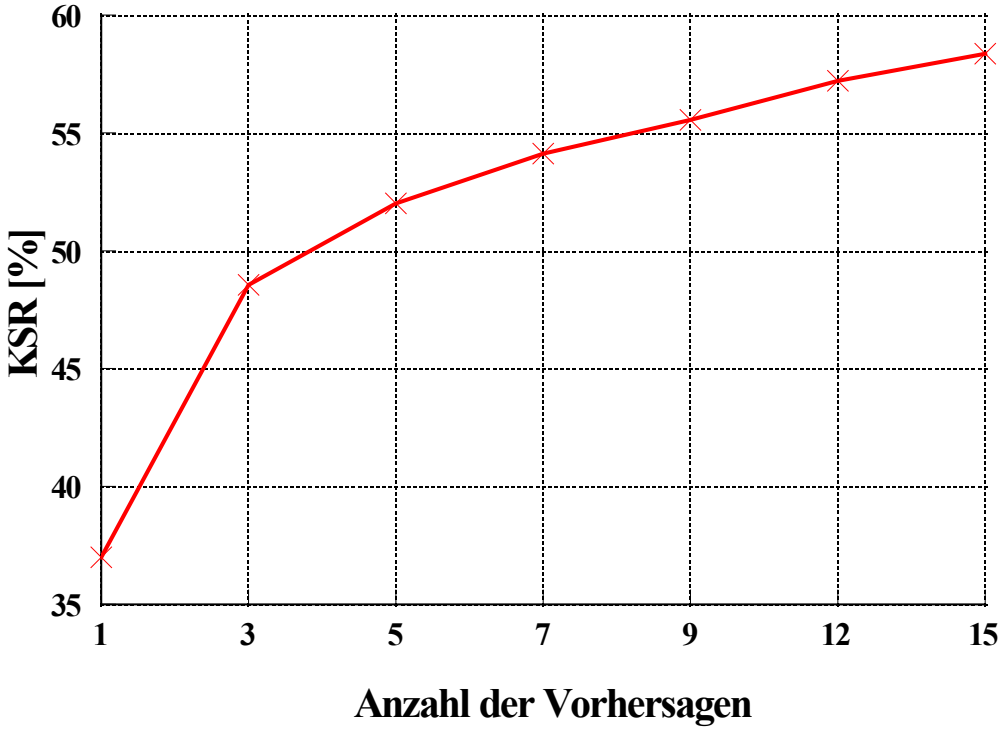
https://emu-software.com/info/ (Duration: 1 min.)

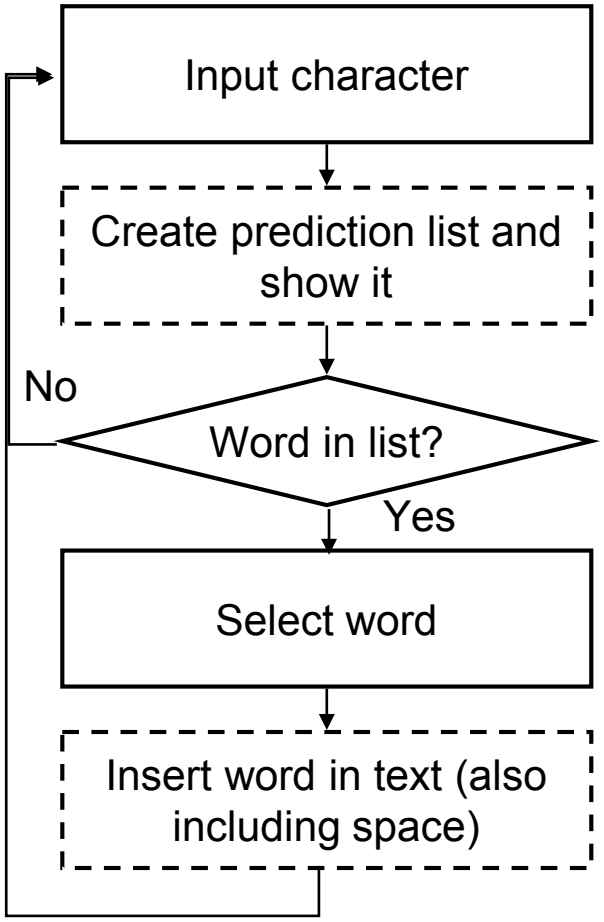


Savings on keystrokes (KSR in%)

depending on the length of the suggestion list

A commercial system is slightly above these levels from short experience





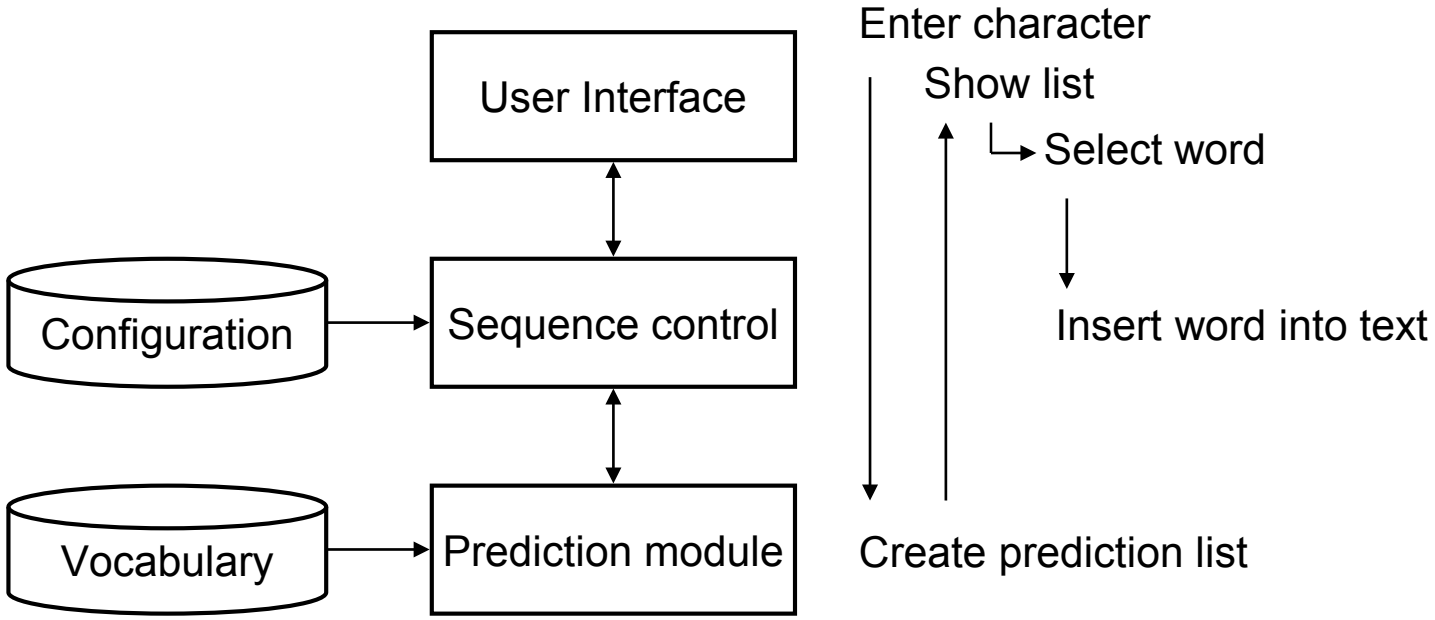
1 keystroke

Attention
Decision
Abstraction

1 keystroke

A word can be written with 1 or 2 keystrokes

Maybe increased cognitive demand, exhausting


User Interface
Configuration
Sequence control
Vocabulary
Prediction module
Enter character
Show list
Select word
Insert word into text
Create prediction list

- Alphabetical
  - Most commonly used
  - Intuitively usable
- By word length
  - Long word at the beginning of the list fits quick selection
  - Hard to search
- By probability
  - Most likely word at the beginning of the list
  - Difficult to understand
- By word classes
  - New idea to investigate
  - Complex list construction may be difficult to understand

Suggestion list

Free positioning

Following the cursor

Alphabetical sorting

Adjustable default list length

Forecast

Multiple word prediction

Word / phrase probability

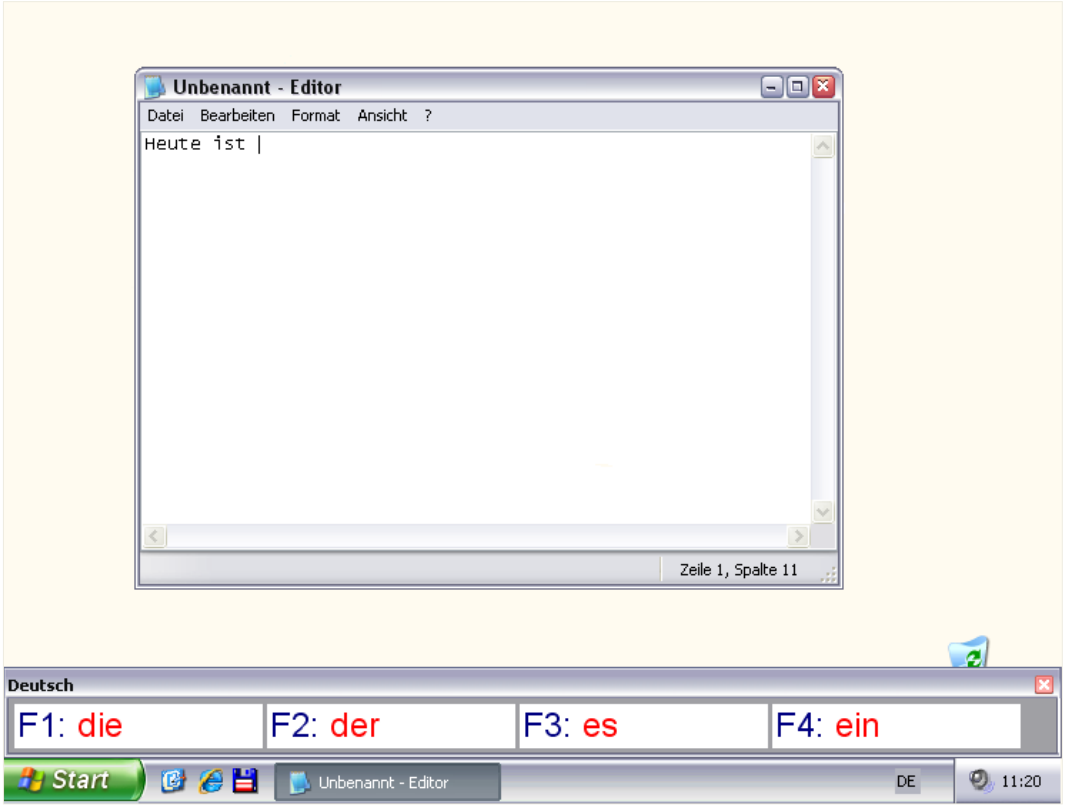
Abbreviation expansion

Prediction of compound words
Generating arbitrarily composed words "from scratch"
Consideration of preceding parts of speech
Two words of one kind do not usually follow each other directly
Suggestions matching the text also with free movement of the cursor
Available in many languages: German, English, French, Italian, Dutch, Swedish, Spanish, Turkish
Dictionary extensible with own texts
Feedback possible through sound and voice output

https://emu-software.com/

- Basic setting suitable for many situations
- Various adjustment options
- Changes mostly directly visible

On border of screen



- Advantages:

Fixed position, easier to find

Text is not obscured

Often used

- disadvantage

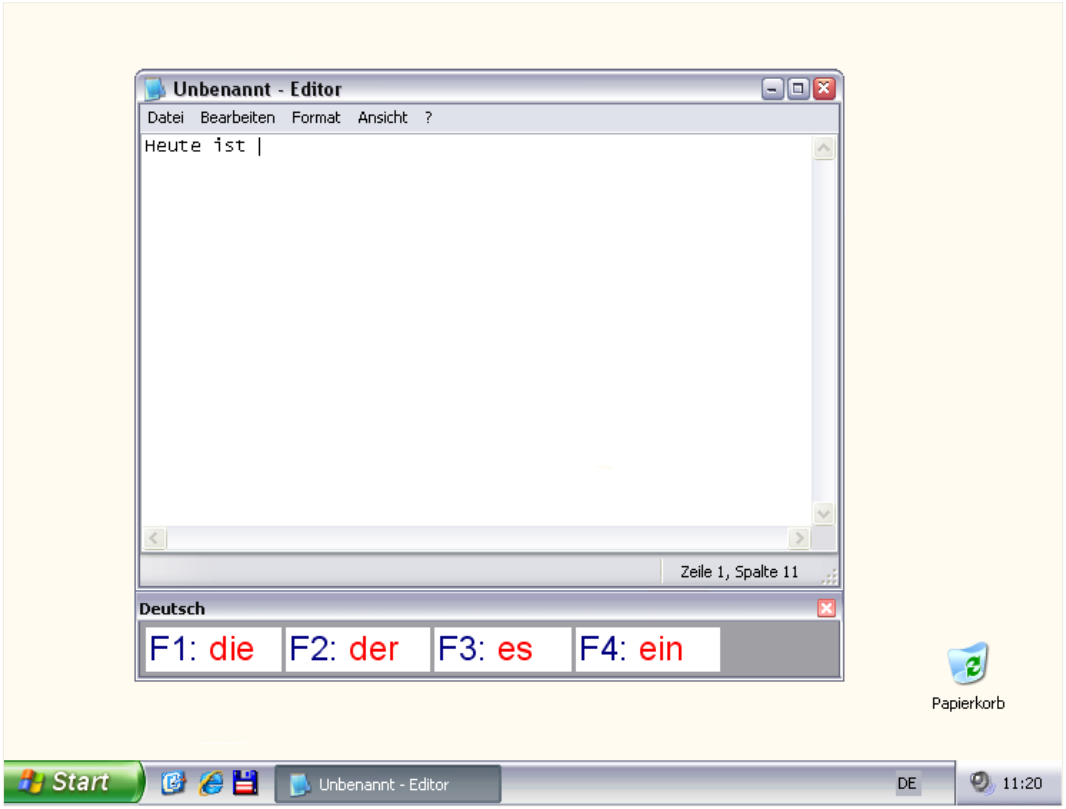
Limited number of suggestions

Limited length of presentable suggestions

Desktop smaller

Big look focus change

Docked below



- Advantages:

Fixed position, easier to find

Text is not obscured

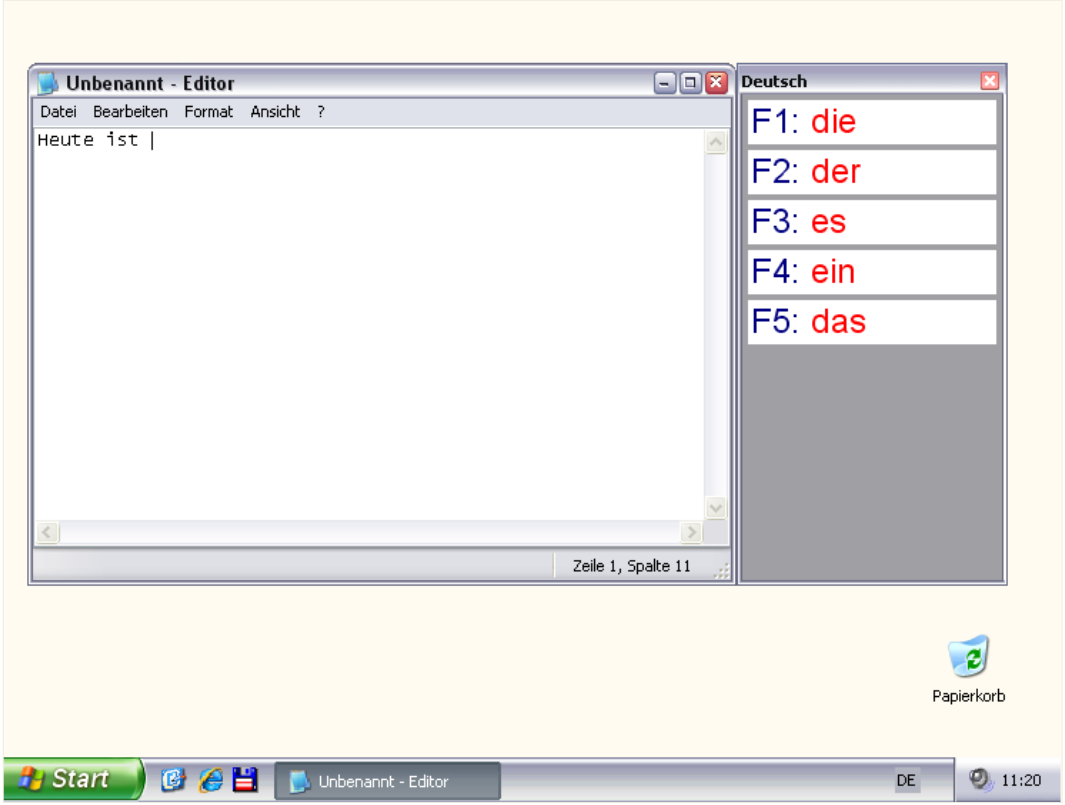
- Disadvantage

Limited number of suggestions

Limited text length

Application window smaller

Docked right



- Advantages:

Fixed position, easier to find

Text is not obscured

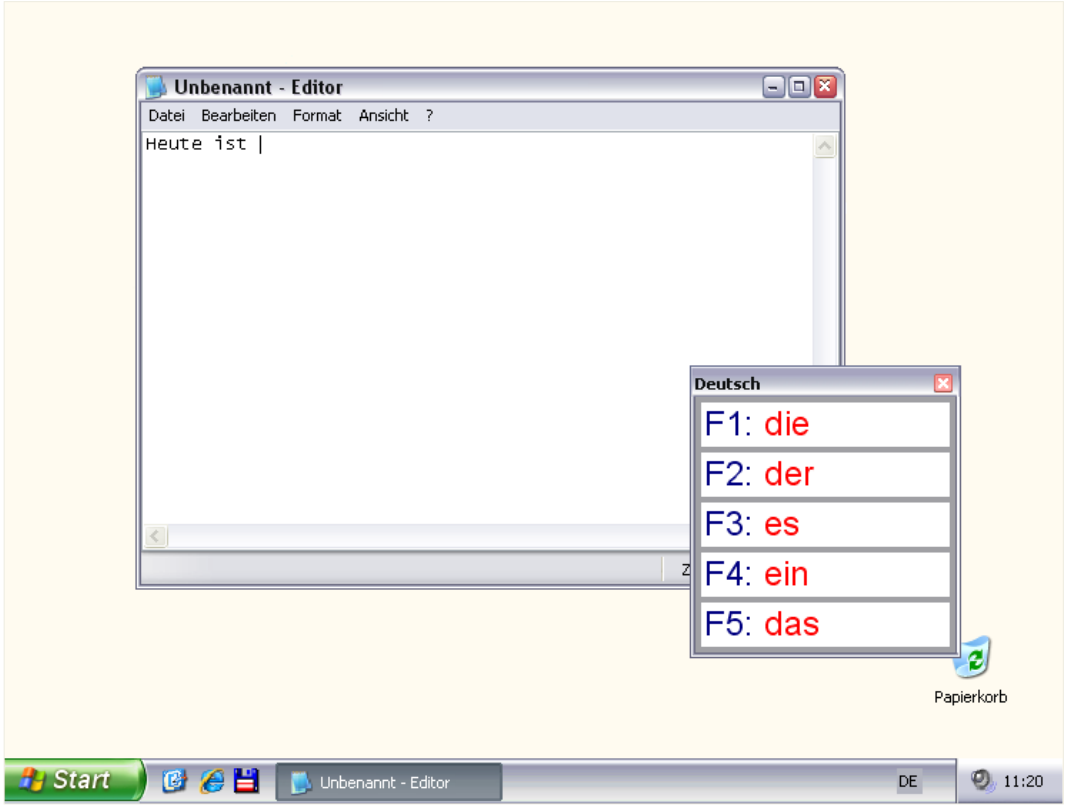
Text length freely selectable

- Disadvantage

Application window smaller

List length depends on window size

Free positioned



- Advantages:

Position according to user request

Avoiding obscuration

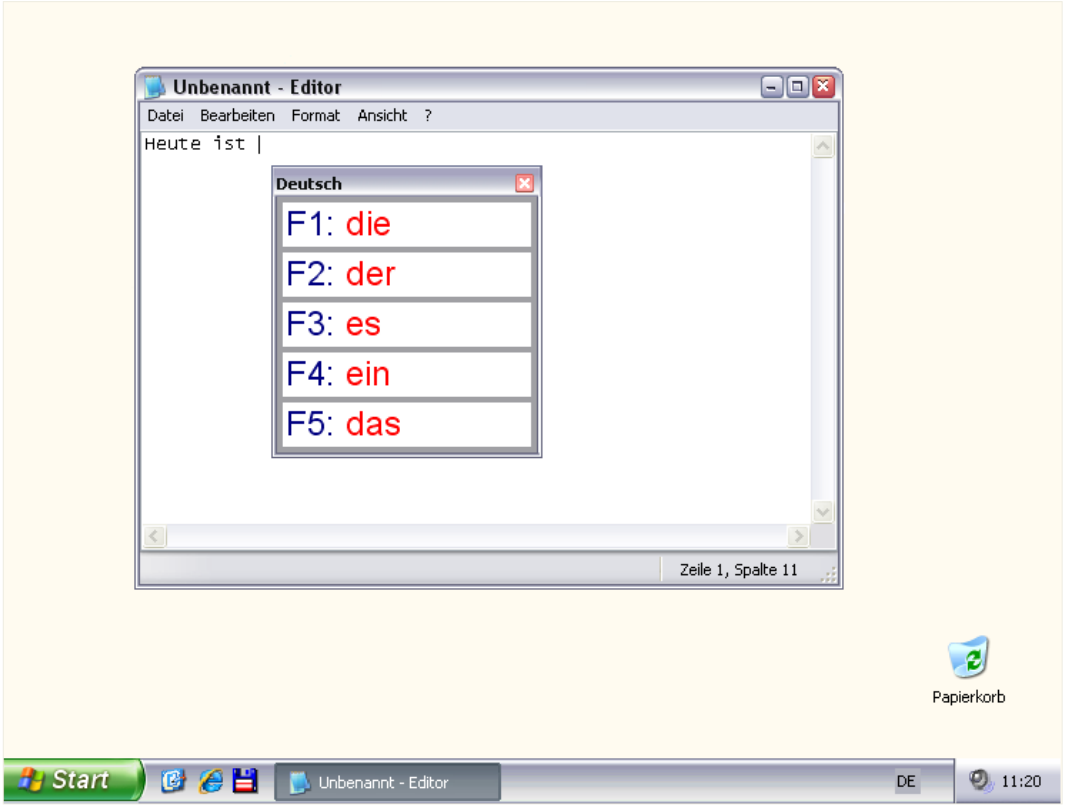
Text length freely selectable

List length freely selectable

- Disadvantage:

Possible look focus change

Following the cursor



- Advantages:

Text length freely selectable

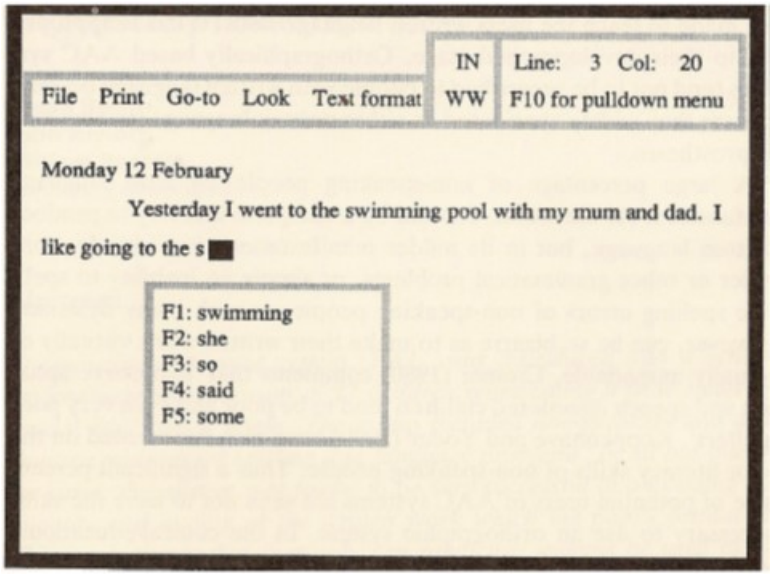
List length freely selectable

Glance focus change low

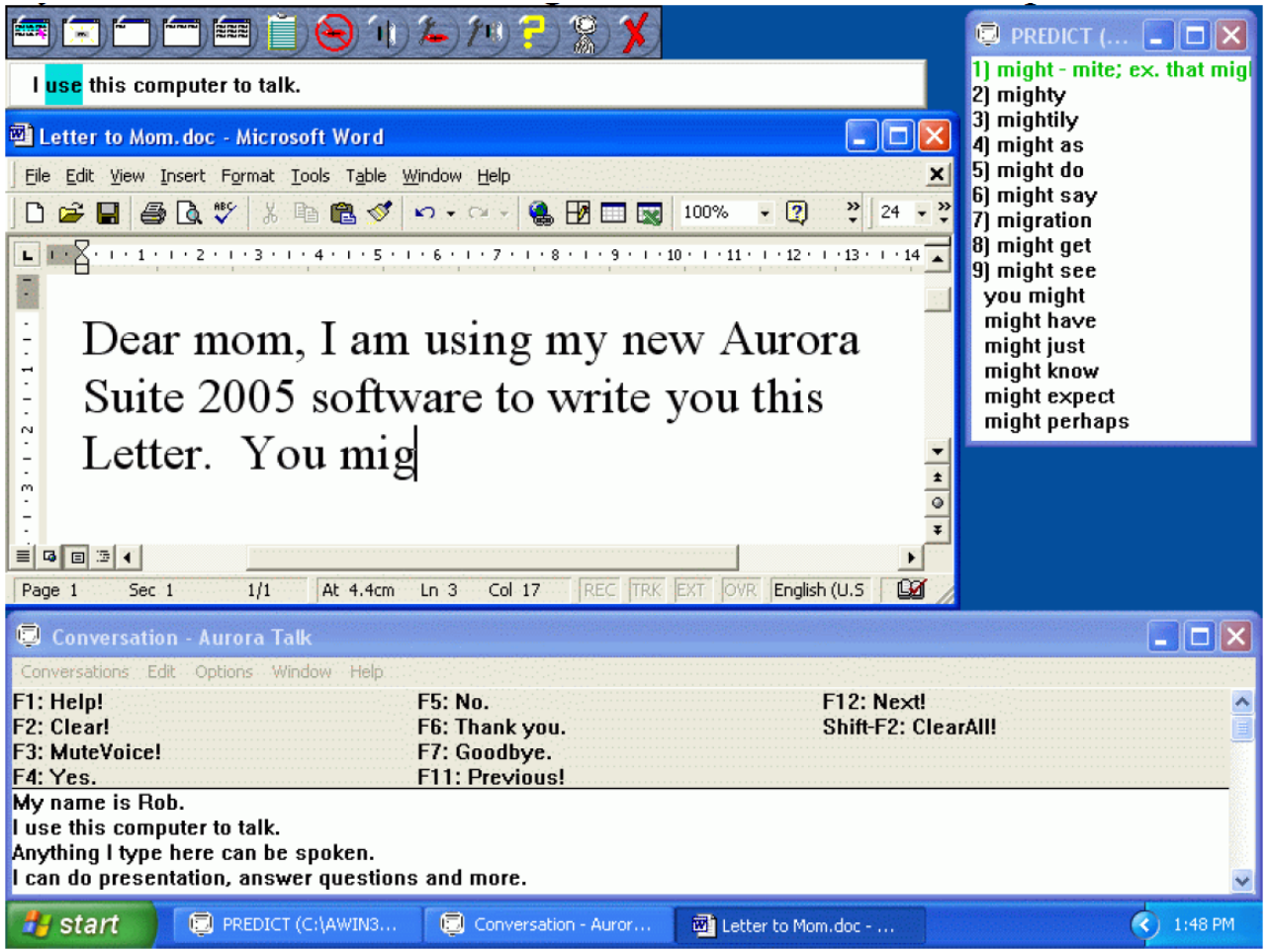
- Disadvantage:

Text may be obscured

Early prediction systems still had handcrafted dictionaries PAL - "Predictive Adaptive Lexicon" from Dundee was able to add new words ("recency") while writing (about mid-1980s)



"*Early predicted systems had hand built dictionaries, but, following a suggestion from a psychologist, Adrian Pickering and colleagues in Dundee produced an adaptive prediction system called PAL (Predictive Adaptive Lexicon) which had an in-built dictionary, but also captured new words and inserted them into this dictionary. The major advantages of PAL were that (a) the frequency of word usage was updated as the system was being used—and thus reflected the individual users vocabulary and (b) predictions were based on how recently the word had been used. (We noticed that, in written text, if an unusual word is used it is often repeated later in the text.) This ensured that the predictions were closely matched to the words that were being used at any one time as well as the vocabulary patterns of a particular user [Newell, A., 1987a, Swiffin et al., 1985]." (cited from* Alain F. Newell, 2011, Design and the Digital Divide - Insights from 40 Years in Computer Support for Older and Disabled People, p. 40)



http://www.aurora-systems.com/

All of our direct, interpersonal communication, while reliant primarily on conveying verbal content, always contains visual components whose importance must not be underestimated.

Body language, facial expressions and gestures contribute much to the interpretation of what is conveyed in words.

Distinction between verbal and nonverbal communication in linguistics:

verbal = based on language convention.
Therefore, speaking, writing, gesturing is verbal.

Colloquially, nonverbal is often referred to as "non-vocal" communication, that is, communication that operates without the use of voice.

Watzlawick describes non-verbal communication as analog communication, verbal communication as digital.

Facial expressions

visually perceptible facial expression

Movements of the face surface
mimic muscles
eyes
mouth

Gesture

Conscious movements especially of the upper extremities (arms and hands, as well as head)

Lexical gestures - based on "linguistic" and cultural conventions (money = rubbing of thumb and forefinger, tapping on the forehead and other "disgraceful gestures")

Pointing gestures

Iconic gestures - illustration of reality with gestures (replica of actions and things)

Body language

Expression in the posture
mostly partially conscious or unconscious

Cannot always be controlled:
Friedrich Nietzsche: "*You may lie with your mouth, but with the mouth you make as you do so you none the less tell the truth.*"

Early optical messaging

Smoke signals and fire signals

As a previously agreed sign (only yes / no):

The victory over Troy (1884 BC) was reported with a 555 km long fire string.

As encoded message:

with hidden and visible torches:

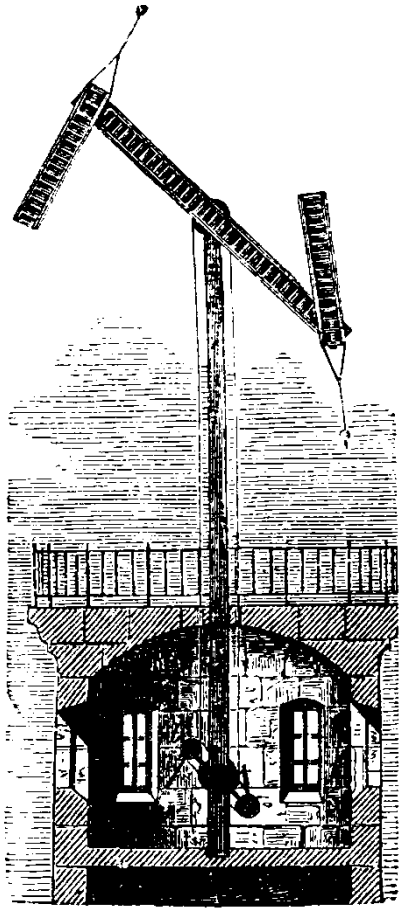
e.g. along the Roman Limes.

Optical telegraph, wing telegraph, semaphore

System of optical-mechanical telegraph lines installed by Claude Chappe in France at the end of the 18th century.

Consisting of towers on which movable wings were mounted. Each position of the wings corresponded to a letter and could be observed and forwarded for long distances from the nearest telegraph station.

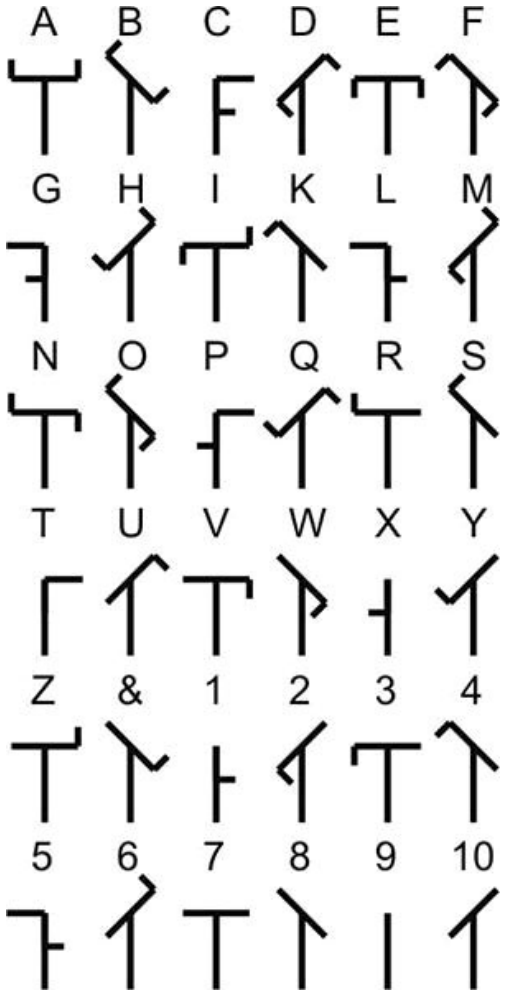
e.g. Paris - Lille, 270 km, 22 stations, runtime 2 minutes.



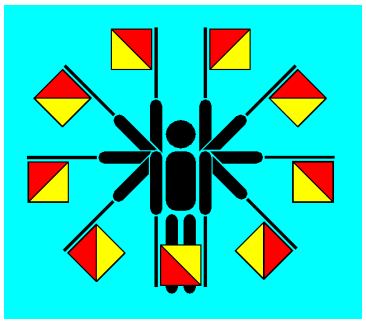
Optical telegraph, wing telegraph, semaphore

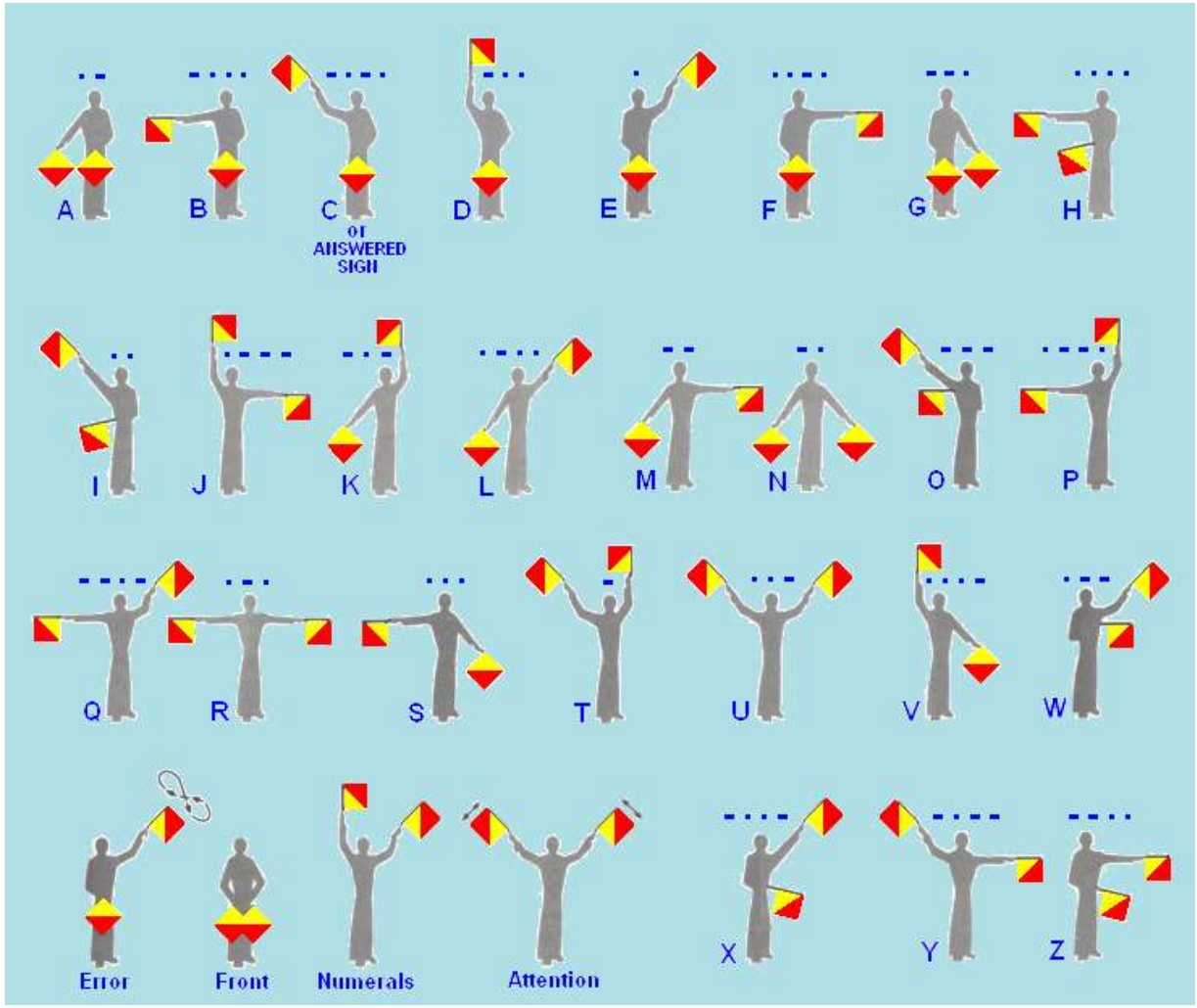
In 1845, France had a nationwide network.

Each of the two signal arms could take seven different positions, the crossbars still two each, which resulted in a total of 7 x 2 x 7 x 2 = 196 different characters.

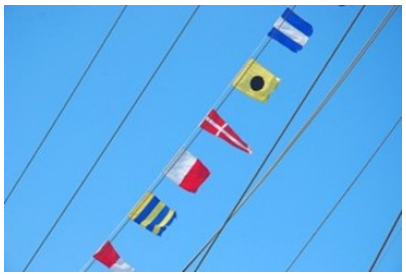


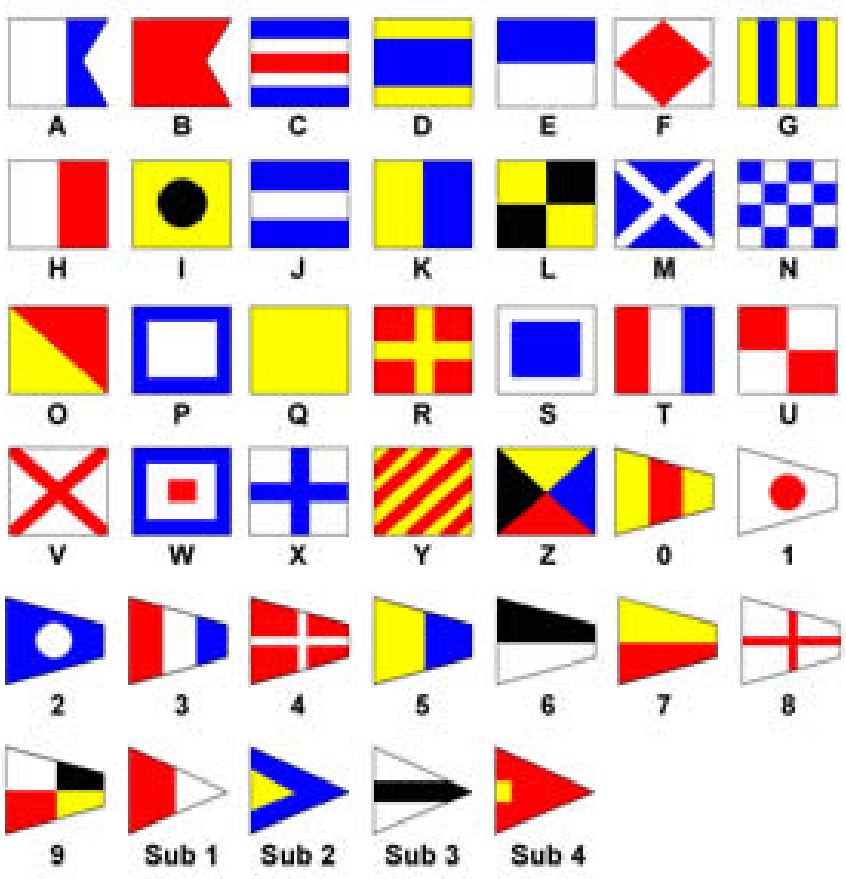
Flag signals between ships





Flag signals between ships





International signal flag alphabet

Visual communication for deaf (or speech-impaired) people

Differentiation: which aspect of the language is converted into the visual modality:

- Lip reading: visual lip appearance (viseme)
- Finger alphabet: visual letters
- Notetaking, subtitling: visual letters
- Cued Speech: visual phonemes
- LBG (phonetic accompaniment sign, manually coded language): visual words 1:1
- Sign language: independent language

Lipreading

Recognition of spoken sounds only from the lips and the mouth position.

Phoneme:
The smallest meaningful sounding segment of a language.

Visem:
Smallest segment distinguishable at the lip image.

Phonemes and visemes

German: about 40 phonemes but only 12 visemes.

Lip reading therefore only conveys 30% of the information
Phonemes like / b / and / p / lead to the same viseme
Throat-formed phonemes are "invisible“.

Co-articulation: different viseme depending on the preceding phoneme: / f / - sound in "Ofen" and "Hafen" is identical, Visem for the / f / - sound is much narrower at "Ofen".

Lipreading

(German)
How is your mother?

Butter?
Aah - thanks!

Lipreading - requirements

Appropriate distance to the speaker

Good lighting conditions

Clear lips - mouth part fully visible

No mustaches

No hand on the face

The speaker should articulate clearly but not overly and speak with perfectly normal volume.

Finger alphabet / finger spelling

Letters are expressed by hand and finger position.

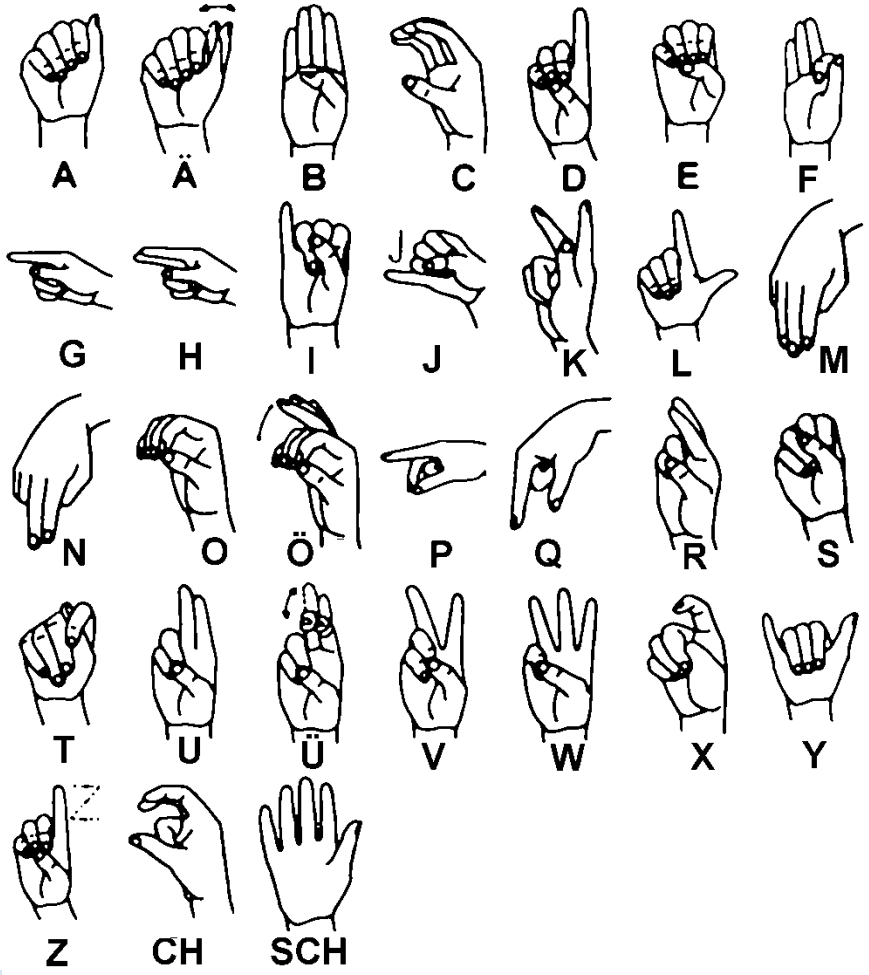
Known since the 16th century, to inform "deaf-mute" children.

The hand and finger positions for the individual letters vary from country to country, but have some similarities.

Often one-handed, but also two-handed variants

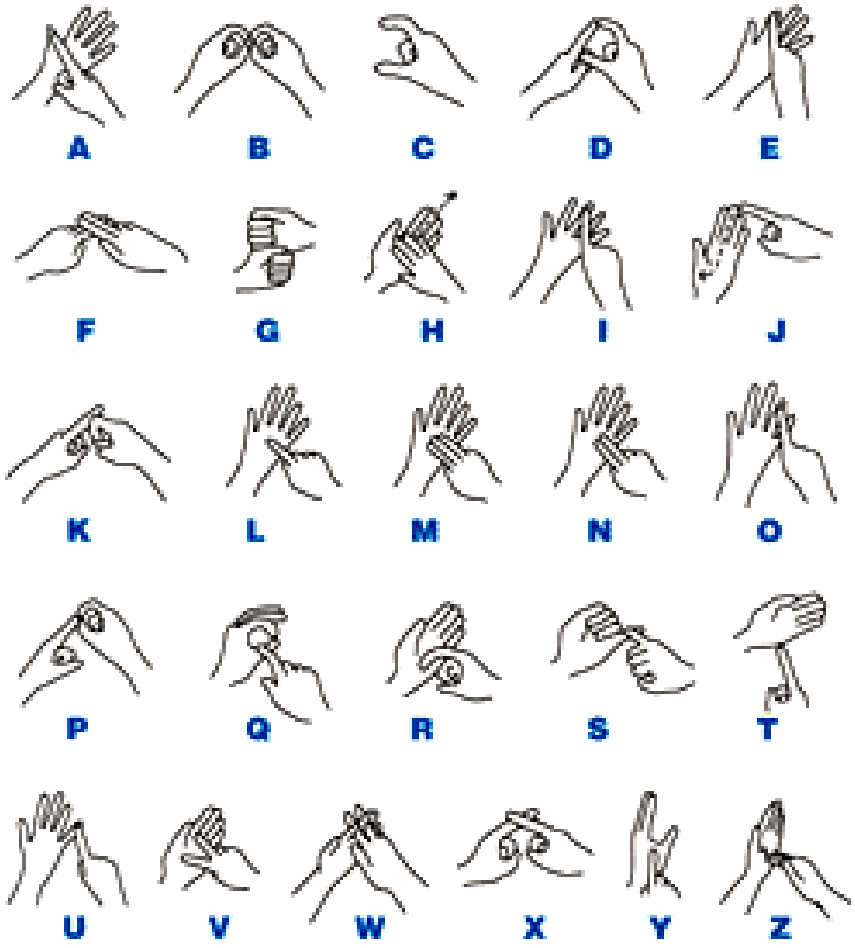
Mostly static, without movement, except "J", "Z" and umlauts

Finger alphabet
used in Germany and Austria



Finger alphabet
UK and Australia

Finger spelling in BSL
(British Sign Language)



Finger alphabet Russian (selection)

Finger alphabet Chinese

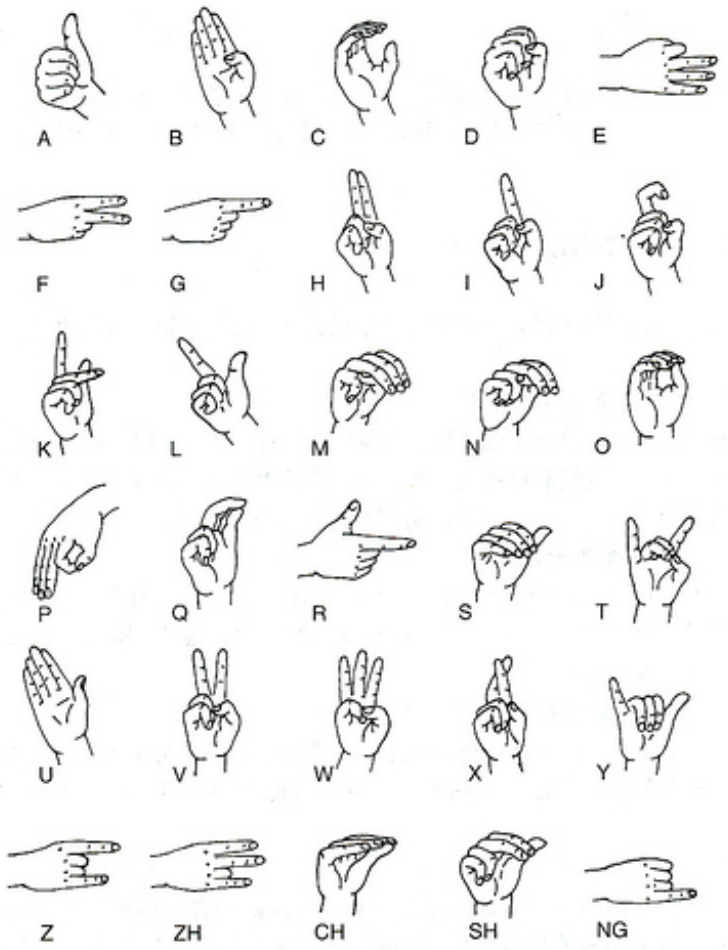


图 8　汉语手指字母

Finger alphabet (cont.)

Use of the finger alphabet requires the appropriate knowledge and practice on both sides.

Since each word is formed letter by letter with hands, the speech rates (even in skilled individuals) are rather modest compared to an auditory conversation.

Example text:

The two spelled words are "internet links" (source: http://www.asta.uni-hamburg.de/users/west/index-d.html)

Outlook to Block 5

VC&HCT

6. Visual Communication
    - 6.3 Sign language
    - 6.4 Signed language, manually coded language
    - 6.5 Cued Speech
    - 6.6 Notetaking and Respeaking
7. Tactile Speaking
    - 7.1 Finger- and Hand alphabetes
    - 7.2 Tadoma
8. Augmentative Voice Creation
    - 8.1 Basics
    - 8.2 Amplification of Voice
    - 8.3 Improvement of Voice
9. Alternative Voice Creation
10. Improvement of Hearing
    - 10.1 History and Basics
    - 10.2 Hearing Aids
    - 10.3 Cochlea Implants (CI and ABI)