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Title	**Impaired Visibility Typeface Test - Report**
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Summary	**Testing the proposed EU traffic typeface prototype "Tern" (for application on VMS and ordinary road signage) for dicriminability of characters in comparison to 3 well reputed examples and give recommendations for further improvement.**
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List of Abbreviations

ANOVA	Analysis of Variance
DIN	Deutsches Institut für Normung
DUK	Danube University Krems
IIID	International Institute for Information Design
In-Safety	Infrastructure and Safety
ISO	International Organization for Standardization
IVTT	Impaired Visbility Typeface Test
LED	Light Emitting Diode
MANOVA	Multivariate Analysis of Variance
Tern	Trans European Road Network
VMS	Variable Message Sign(s)
χ^2 test	Chi-square test

Typography Glossary[1]

Aperture:	Partially enclosed, (rounded) negative space in some characters such as n, h, u, C, S, the lower part of e, or the upper part of a double-storey a.
Apex:	Point at the top of a character such as the uppercase A where the left and right lines meet.
Arm:	The arm of a letter is a horizontal line that does not connect to a stroke or stem at one or both ends. Examples: T, F, E, he diagonal upward line on K.
Bowl:	A (curved) part that encloses circular or curved "empty" space (counter) such as given in d, b, o, D, and B.
Chin:	The right angled line on G.
Counter:	Enclosed circular or curved negative space (white space) of some letters such as d, o, and s.
Cross-bar:	The (usually) horizontal line across the middle of uppercase A and H is a crossbar. The horizontal line enclosing the bottom of the eye of an e is also a crossbar.
Cross-stroke:	The horizontal line across the stem of a lowercase t or f is a cross stroke.
Extender(s):	Part of a letter that extends above the x-height (ascender) or below the baseline (descender).
Eye:	The enclosed space in a lowercase e. See Counter
Link:	Small, usually curved line that connects the bowl and loop of a double-storey g.
Negative space:	"Empty" space (in-)between parts of a character.
Stem:	The main, usually non-curved vertical stroke of a letter as n L, l, d, B, and p. H, N, and M have two stems.. Letters such as C or S do not have a stem.
Stroke:	Main diagonal line of a letter such as in N, M, or Y.
Tail:	Descending stroke on Q, descending, (curved) diagonal stroke on K or R. Also descender on g, j, p, q, and y.
Terminal:	(Curved) end on letters such as the bottom of C or e or top double-storey a.

[1] Excerpts from http://desktoppub.about.com/cs/typeanatomy/a/basic_anatomy.htm (7.1.2007) by Jacci Howard Bear.

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Participating Bodies / Credits

This test was carried out under the Sixth Framework Programme of the European Commission, within the Project "IN-SAFETY", Activity A2.4 "Content structure of pictorial and verbal messages on VMS and typeface ".

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1. Introduction

The IN-SAFETY Project – which the actual study is part of – can be characterized as a multifaceted research project to enhance the self-explanatory and forgiving nature of roads. It aims to use intelligent and intuitive combinations of new technologies and traditional infrastructure best practice solutions to improve the common safety standard of the European road-network and its transnational traffic-system. According to that the research in development and optimization of traditional *traffic signs* and modern *road information systems* is one central field of study.

Since drivers tend to go farther than ever before, crossing several countries in one single trip, the reduction of possible driver-confusion by homogenizing the different national approaches to one common traffic-safety-standard becomes an important matter.

While one of the main tasks in this European traffic signalling context is to develop solutions and techniques to overcome the numerous cultural differences and minimize the use of differing local *languages* (e.g. by developing comprehensible pictograms as in the In-Safety work package A2.2), verbal messages and written text cannot be substituted completely.

Traditional traffic signs - as well as the content of modern *Variable Message Signs* (VMS) – gain there full informational value and precise meaning often only by additional written remarks or verbal extensions (such as names of places, chronological restrictions or other context-specifications).

For all those cases the question of appropriate *legibility* or *readability* of the textual information gains vital importance. Especially messages displayed at Variable Message Signs (VMS) on motorways, which are passed with high velocity, have to fulfil the conditions of maximum legibility and easy accessibility – all the more if *impaired viewing conditions* (such as darkness, rain or fog) are taken into account.

The conducted research in typeface-development (IIID) and its evaluation consequentially had to pay attention to (1) the attainability of the highest achievable legibility factor, (2) the different requirements of fonts intended for printed signs or dynamic VMS-matrix-displays and (3) the comparative analysis of new and existing typefaces.

Therefore the three most influential types of European traffic-fonts (out of previously acquired 28) were selected for extensive evaluation: the so called "*Transport*" ("Transport D" and "Transport 360)" / GB, see Fig. 2), the "*RWS*" ("RWS Ee VL" and "ANWB Ee" / NL, see Fig. 3). and the German standard-font "*DIN*" ("DIN- Mittelschrift" and "MITT2R" / D, see Fig. 4) – each of them twice: as "normal" version for static signs and as "VMS" version for the rasterized matrix displays of variable message signs.[2]

These most influential typefaces – representing best practice examples – were chosen for examination. Character by Character were compared and disadvantages/advantages concerning legibility evaluated by type design experts.

Equipped with this knowledge, a new type-design-process was conducted, resulting in the creation of the proto-typeface "*Tern*" (abbreviation for Trans European Road Network) (see Fig. 5).

[2] The British traffic typeface "Transport" is to be regarded as the most influential in Europe. It is in use – as localized versions of the font – in several European countries, e.g. Greece. Its counterpart for VMS application is in use on the British islands. The "RWS" of the Netherlands, like Transport, was designed with regard to legibility. Its VMS-version is in use on Dutch roads as well. The "DIN-Mittelschrift", the German standard, shows a more application based approach, since it is drafted only out of circle-parts and straight lines. Several localized versions are in use in European countries (e.g. Austria). MITT2R, its VMS-version, is used on motorways throughout Germany.

Its performance profile should allow

- for superior legibility,
- early recognition of characters,
- ability to cater 25 EU-languages (Latin based scripts and Greek),
- dual capacity for the technical aspects of normal road signs as well as VMS-displays,
- whilst upholding a formal unity in design throughout these applications.

After completion, this prototype was tested extensively in comparison to the three best practice examples. As the most important outcome, the resulting data – depicted in this report – is actually evaluated to further enhance the legibility and discriminability of the new typeface and its single characters.

2. Methods and Materials

2.1. Test Design and Test procedure

The configuration of the experimental equipment can be envisioned as the usual setting of a visual test (see Fig. 1): a test person standing in front of a screen, reading aloud what he or she is able to perceive - and an observer who is recording and checking the answers. What was shown to the subjects in this particular situation (on a notebook-display with a resolution of 1024x789 pt. at 15'' display) were different combinations of characters, in form of six letters per page and 50 to 100 pages per testing series. Those series (A, B and C) were divided into several sections of different typefaces and had to be read by the subjects from three different distances.

Fig. 1: Test-Setting

Series A and B contained 50 pages (with a total amount of 348 characters), serial C 100 pages (including 612 characters) (see Table 1).

Serial A	RWS; RWS VMS; DIN; DIN VMS	Characters: 348
Serial B	Transport; Transport VMS; DIN; DIN VMS	Characters: 348
Serial C	Tern; Tern VMS; DIN; DIN VMS	Characters: 612

Table 1: Test-Series and implemented typefaces

To simulate "impaired visibility conditions" each test person was asked to sequentially spell its assigned serial aloud out from one of three distances. Those distances corresponded to different levels of visual acuity – and therefore to different levels of visual impairment. (see Table 2 *"Impaired Visibility Typeface Test",* IVTT).

IVTT:	Distance 1	5.50 m	**Acuity**[3]	1.00
	Distance 2	7.40 m		0.65
	Distance 3	8.30 m		0.50

Table 2: Impaired Visibility Typeface Test - Viewing Distances and Levels of Acuity

The test of one person lasted for about 15 (Series A/B) and 30 minutes (Serial C) and was conducted in combination with the "Content Structure Test on animated pictograms" (IN-SAFETY Work Package A2.4 - this short test was chronologically inserted in the middle of the viewing test, hence allowing the test persons to recover from emerging eye fatigue.) In this framework a total amount of 150 participants with varying demographic characteristics and diverging driving experience were asked to examine the discriminability of the exhibited characters[4].

2.2. Materials

2.2.1 Questionnaire

At the beginning each subject was requested to answer a short questionnaire. Beside demographical data (such as *age*, *gender*) also information about the individual *driving experience* (exposure to the road per year) and the possibly existing visual defects (dioptric values and time since the last consultation with an oculist) were gathered.

2.2.2 Typefaces

Subsequently one (out of three) series containing two (out of four) different typefaces was presented. Within each serial one selected font was contrasted to the "DIN"-Font that acted as reference. In this way, the British "Transport" (Fig. 2), the Dutch "RWS" (Fig. 3) and the newly designed "Tern" (IIID, Fig. 5) were successively compared to the German "DIN" (Fig. 4). Concerning "Tern" and "DIN" all characters of the alphabet, upper and lower case, and including numerals, were shown. Relating to "RWS" and "Transport" mainly characters were presented which are known to be hard to read or easy to be confused with similar looking characters. All fonts were shown in "normal" style - dedicated to *static* traffic signs, as well as in "VMS" style - dedicated to *variable* messages signs (as a comprehensive scheme - see again: Table 1, as well as the following Figures 4-7).

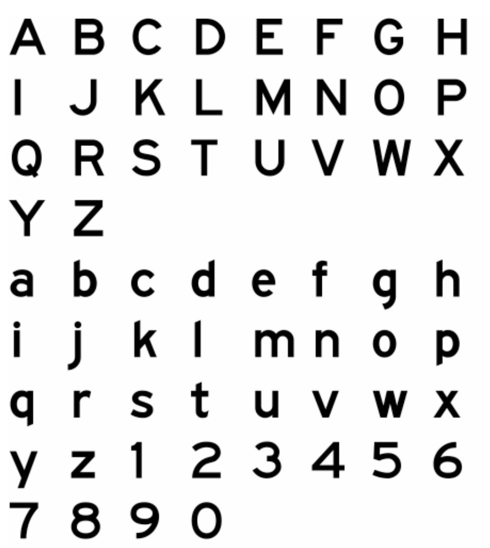
[3] Technical basis for 100% acuity calibration: 1 minute of arc corresponds to a height of 1.45 mm at 5.5 meters viewing distance. Our reference was the letter "e" in small caps. To see all necessary details, an viewing angle of 5 minutes of arc was needed. Therefore a height of 7.25 mm for the e in small caps is needed for 5 meters viewing distance. Other distances where interpolated.

[4] These participants were selected in accordance to ISO 1989 and 2001 (see Brugger, 1999).

Transport

Transport VMS

Fig. 2: The "Transport" typeface in comparison (normal and VMS display types).



RWS

RWS VMS

Fig. 3: The "RWS" typeface in comparison (normal and VMS display types).

	
DIN	DIN VMS

Fig. 4: The “DIN” typeface in comparison (normal and VMS display types).

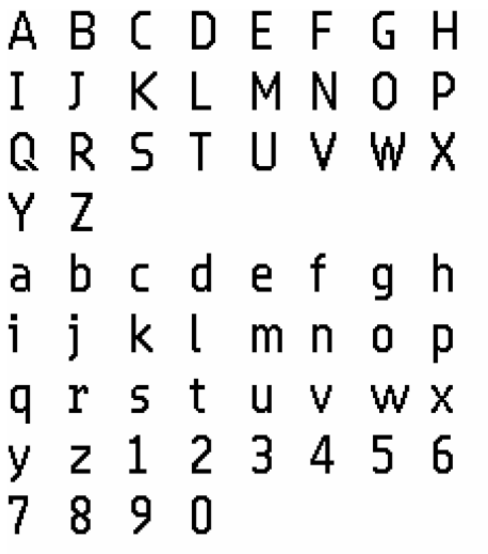
	
Tern	Tern VMS

Fig. 5: The “Tern” typeface in comparison (normal and VMS display types).[5]

[5] Tern Typeface first version. For the final version see chapter 7 (Fig. 18 and Fig. 19).

2.3. Making Typefaces comparable

For the legibility of typefaces for conventional road sign application, the given space defined by the edges of a board limits the overall height of a single line of text and through this, the space vertically available for characters (from top of the ascender to bottom of the descender). If a typeface bears too big a difference of height between upper a lower case letters, the latter become unnecessarily small, resulting in a less legible typeface. To reflect real life situation, all four "normal" test-typefaces were enlarged / respectively shrunk to fit the same given height (see Fig. 6).

Fig. 6: Calibration of typefaces for normal display type.

To allow for the comparison of VMS typefaces, the need was identified that all typefaces to be tested have the same lower case letter height, since the prototype typefaces differ on ascender and descender height, but bear the same vertical height in lower case (13 LED-dots = 13 pixels). Interestingly, DIN VMS´ descender (see "g") exceeds the length of all other VMS-fonts, which should help to increase legibility, while RWS VMS, bearing smaller upper case letters, might have a disadvantage here (see Fig. 7).

To simulate the ruggedness of this VMS-typefaces´ appearance when shown on a LED based matrix display, it was chosen to depict them in rough pixel resolution, one pixel representing one diode.

Fig. 7: Calibration of typefaces for VMS display type.

2.4. Leading Questions

The entire structure of the test - as well as the analysis of the collected data - was aligned with the leading question of maximum discriminability of characters, which should lead to higher legibility.

So the research interest aimed at the detection of statistical differences between the selected typefaces, concerning their general (non-)legibility or confusability with respect to specific “problematic” characters (the so called “usual suspects”, derived from Herbert Spencer in “The Visible Word”, published 1969). Hence the question was: Which typeface yields fewest reading errors and simultaneously least confusion of characters?

Therefore the first task was to identify one specific font (out of four) that yielded most legible characters– in “normal” and “VMS”-version, as well as under normal and impaired visibility conditions (i.e. also from greater distances than the equivalent of 100% acuity).

Secondly: Are the assumptions on problematic characters, proposed by Spencer in 1969, still valid in the light of this newly developed testing procedure? Typeface experts were consulted (Erik Spiekermann, IIID; Ellen Lupton, RNIB / Royal National Institute of the Blind) to expand Spencers list by evaluating recommendations on characters to be considered as problematic.

Third question: Comparing the performance of single problematic characters of the tested typefaces- which font scores best on specific letters/numbers (e.g. "4"), which scores the worst, and why? Judging the differences in typeface design for single character provides insights on how to optimize their legibility for the new traffic typeface "Tern", which will subsequently undergo an improving redesign according to the findings.

So the primary intention of the test was the detection of empirically validated data relating to functional (font-)design. This was an interesting approach, since there is usually only a very weak or even no connection between typeface design (regarded as a creative “art form”) and testing (as a potential “threat” to new exceptional developments). Especially the intended *functional* (in contrast to *aesthetical*) design - that is of crucial relevance for everyday-safety and particularly road safety – has to be considered to benefit almost necessarily from the chosen empirical examination.

3. Results

3.1. Participants

3.1.1. Data Preprocessing

Participants who stopped answering at any time of the test were excluded from analysis due to the risk of motivational deficits (it was hard to solve) or positional effects. In Table 3 the resulting sample sizes for each series are listed in brief.

	Recorded data	Excluded	Analyzed
Series A (RWS, RWS_VMS, DIN, DIN_VMS)	40	7	33
Series B (Transport, Transport VMS, DIN, DIN_VMS)	45	10	35
Series C (Tern, Tern_VMS, DIN, DIN_VMS)	37	7	30

Table 3: Resulting sample sizes after data preparation

The sample sizes will be reduced further from time to time in the next chapter in case of missing data values.

3.1.2. Age

Much importance has been attached to the selection of comparable and representative samples for each series. Hence several tests with key variables that describe the sample have been conducted to assure a sufficient quality of the selection. The variable *age* is one of these key variables.

		N	mean	standard deviation	min.	max.	K-S
Age	A	33	29.73	9.609	19	55	0.241
	B	32	27.59	10.019	19	66	0.126
	C	30	28.67	9.448	19	58	0.069
	Total	95	28.67	9.636	19	66	

Table 4: Descriptive statistics for the variable age. Normally distribution assumed for K-S values > 0.05.

Age turns out to be normally distributed in each series (K-S: $p > 0.05$, see Table 4), a result that makes statistical testing easier. Further no significant differences in the age of the participants can be found between the series[6]. The mean age was 28.7 over all groups, age ranged from 19 to 66.

3.1.3. Driving experience

A crucial variable in traffic studies is usually the exposure to the road per year. Although this variable does not look decisive for a legibility test at a first glance, the information illustrates the representativeness of a driving population. For an overview, see Table 5.

[6] ANOVA : $F_2 = 0.393$, $p > 0.05$, no significance with Bonferroni post-hoc tests.

Exposure		N	mean	standard deviation	min.	max.	K-S
	A	33	17463.64	15838.83	300	60000	0.544
	B	32	15865.63	14088.10	0	60000	0.247
	C	29	12558.62	12065.43	1000	50000	0.379
	Total	94	15406.38	14156.64	0	60000	

Table 5: Descriptive statistics for the variable "exposure".

Like the variable *age*, exposure also normally distributed and no significant differences were computed[7]. The mean exposure is reported to be on average about 15.400 km each year, up to 60.000 at maximum.

3.1.4. Gender

With regard to the gender of the participants women seemed to be slightly stronger represented than men (54,8% compared to 45,2%, see Table 6), but statistical tests showed no significant differences[8].

			Gender		Total
			Male	Female	
Series	A	N	13	18	31
		%	41.9%	58.1%	100.0%
	B	N	12	20	32
		%	37.5%	62.5%	100.0%
	C	N	17	13	30
		%	56.7%	43.3%	100.0%
Total		N	42	51	93
		%	45.2%	54.8%	100.0%

Table 6: Frequency distribution of the variable gender.

3.1.5. Visual defects

On one hand, a basic requirement to become a participant of the test was that visual defects had to be corrected to normal. On the other hand it was necessary to include some variability with respect to visual abilities to emulate a naturalistic selection of the driving population. Although it was out of the scope of this test to build up groups with specific impairments, it was necessary to include people with visual defects (corrected to normal) in every series and - for comparability reasons - these groups had to be distributed as uniformly as possible throughout the series.

[7] ANOVA : $F_2 = 0.951$, $p > 0.05$, no significance with Bonferroni post-hoc tests.

[8] Pearsons/LR Chi²=2.492/2.494, $p>0.05$

			Visual defects (corrected to normal)		Total
			yes	no	
Series	A	N	18	15	33
		%	54.5%	45.5%	100.0%
	B	N	19	13	32
		%	59.4%	40.6%	100.0%
	C	N	17	12	29
		%	58.6%	41.4%	100.0%
Total		N	54	40	94
		%	57.4%	42.6%	100.0%

Table 7: Frequency distribution for the question „Do you have any visual defects?".

Once again, the test for differences within the series showed no significant results[9].

3.2. Comparison of problematic characters, the "usual suspects" in different typefaces

There is a list of usual suspects which are frequently mistaken, namely the characters B, 4, e, v, Q, l, i, j, I, 1, 3, 5, S, p, G, 9, f, b, a, 6, D, g, h, y, 8, q, Z, 7, n (see Spencer, 1969). These characters and some other presumably difficult numbers were tested in the following sections.

3.2.1. Frequency of correct answers for each font in overview

To compare different typefaces, the frequencies of correct answers were used. For each series, the same sample of 29 characters was tested. We called them the "usual suspects" because they are known to be easy confusable characters[10].

In a first step, the correct answers concerning DIN fonts were compared between series A (RWS), B (Transport), and C (Tern) to check if the randomized assignment of the participants to the series had worked as intended and to ensure that there were no significant differences in the vision capabilities between these 3 groups of participants. Although series C consisted of 62 characters of Tern and DIN, for this analysis only a subset of 29 were used, which matched with the other series A and B.

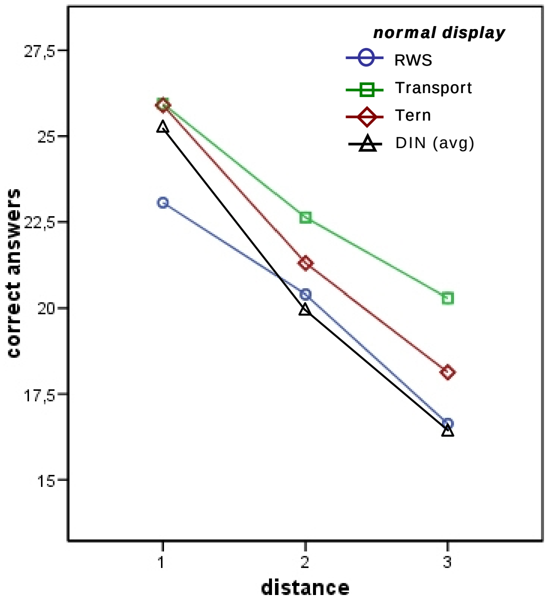
There were no statistically significant differences between these three groups of participants within DIN fonts, the vision capabilities of the 3 groups can therefore be treated to be similar[11]. This result is essential for later sections, because DIN fonts will be used as reference font for further analysis.

In the next figures, statistics on correct answers between each series for the three viewing distances 1 (100% visual acuity), 2 (65% acuity), and 3 (50% acuity) are shown. On the right side, the DIN fonts are depicted per series, on the left side, all fonts are diagrammed (see Fig. 8 and Fig. 9).

[9] Pearsons/LR Chi²=1.79/1,78, p>0.05

[10] As stated earlier, this selection was generated up by Stefan Egger, based on the findings of Spencer, 1969.

[11] Statistical assumptions for the statistical analysis of variance (ANOVA) to test the differences between the fonts were satisfied by means of normal distribution (per distance/per series) and homogeneity of variances.



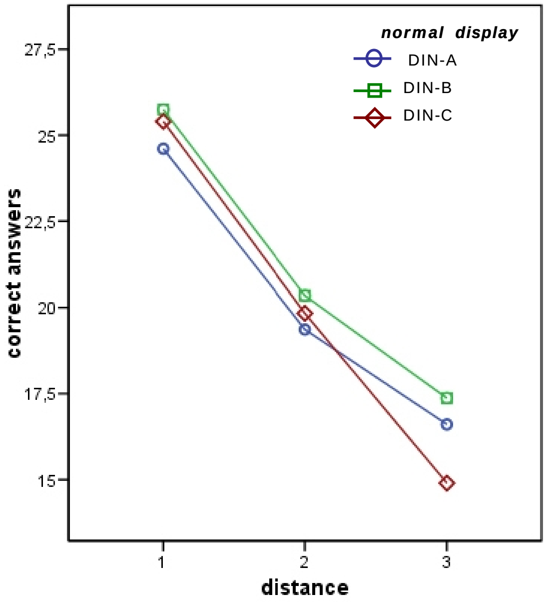


Fig. 8: Correct answers for testfonts in normal display type (left hand side). DIN is averaged over the series A, B, C.

Fig. 9: Correct answers for reference font (DIN) in normal display type per series (right hand side). The splitting of DIN into series A, B, C is necessary for the section 3.3, where the fonts will be compared by an individual baseline (series-based).

As expected, the frequency of correct answers decreases with increased viewing distance. The differences between the series are slight and – as stated above – statistically not significant. The reason for a stronger decrease in the legibility in series C of the DIN typeface could depict the fatigue of the participants due to the fact that they had to solve nearly twice as much characters than the participants in the other series.

For any other font than DIN, the differences are more evident. RWS seems to be the font with the lowest frequency of correct answers. Tern shows a stronger decrease in the farthest distance. Tern is tested only in series C, the series with more characters and the risk of fatigue effect. This factor will be taken into consideration in one of the next chapters when DIN results were used as reference for every series separately (see section 3.3) The Transport typeface turns out to be the font with most correct answers for all distances.

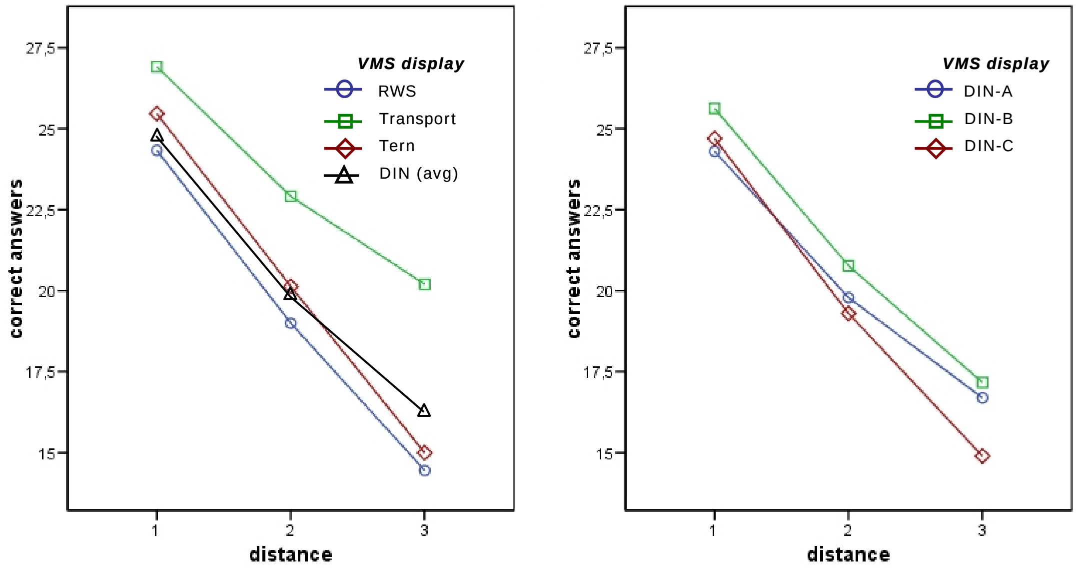


Fig. 10 (left hand side): Correct answers for testfonts in VMS display type. DIN is averaged over the series.

Fig. 11: (right hand side): Correct answers for DIN-fonts per serial in VMS display type.

A similar picture presents itself for VMS display (see Fig. 1210, Fig. 1311). Results for RWS indicate this typeface to be the one with the least correct answers in sum, followed by DIN and Tern as second best. The best performances are with the Transport font.

3.2.2. Comparison of RWS vs. DIN-font

Due to the lack of statistical preconditions[12] no tests between the testfonts (RWS, Transport, Tern) and the DIN-reference font were possible with respect to different distances. T-Tests with aggregated data over 3 distances were computed instead[13] to make a comparison of the mean values. In series A the RWS fonts can be tested against the reference letters of the set of DIN fonts. Just like in the sections before, only the difficult "usual suspect sample" of fonts was used.

T-Tests resulted in significant differences in mean values for VMS fonts while the differences in normally displayed fonts turned out to be statistically inconsiderable[14].

	N	mean	std.dev.	min.	max.
RWS	33	20.03	3.80	10.00	26.33
DIN	33	20.19	4.37	9.67	27.00
RWS VMS	33	19.26	4.51	6.67	28.67
DIN VMS	33	20.26	4.27	8.33	27.67

Table 8: Correct answers for RWS and DIN (normal display and VMS)

As presented in Table 8, participants answered for DIN-Fonts more often correct than for RWS-Fonts in normal display. For VMS display, the compared typefaces are equivalent with respect to proper answers.

[12] only partially normal distributed, no homogeneity of variances, as well as covariances und errorvariances

[13] approx. normal distributed, homogeneity of variances, bonferroni-corrected

[14] difference=-1.000; t[32]=-3.842;p < 0.01

3.2.3. Comparison of Transport vs. DIN-font

Comparing Transport and DIN fonts, the differences were significant[15] regardless of the display format. More correct answers have been provided for Transport than for DIN letters in both cases (tested in series B, see Table 9).

	N	mean	std.dev.	min.	max.
Transport	35	22.95	3.96	12.67	28.00
DIN	35	21.15	4.21	8.67	26.67
Transport VMS	35	23.34	3.67	14.67	29.00
DIN VMS	35	21.19	4.21	10.33	27.33

Table 9: Correct answers for Transport and DIN (normal display and VMS)

A comparison of the absolute values like mean and min/max statistics shows best results for series B (mean between 21.15 and 23.34). Although these results look promising it has to be kept in mind that the participants in the B-series score generally higher than participants in the other series.

3.2.4. Comparison of Tern vs. DIN-font

Tern scores significantly better[16] than DIN in normal display with respect to the frequency of correct answers. The results for VMS display show no meaningful differences.

	N	mean	std.dev.	min.	max.
Tern	30	21.78	3.86	12.00	27.67
DIN	30	20.04	3.23	14.33	27.33
Tern VMS	30	20.20	4.16	11.00	28.33
DIN VMS	30	19.63	4.27	10.00	26.00

Table 10: Correct answers for tern and DIN (normal display and VMS)

In Table 10 the basic statistics for the aggregated data over 3 distances for Tern font are listed (series C).

3.3. Explorations on the impairment factor

In the previous section the distance data was condensed to a single average value. In the following section, the performances of the fonts between the distances to the display board - the crucial factor for impairment - are in focus. In order to put everything together, multivariate analysis of variance (MANOVA) with repeated measures together with univariate post-hoc tests have been used. With this powerful packet of analysis, some key factors like typefaces, distances and display types can be analyzed both separately and in their interrelation.

As described earlier, DIN fonts qualified as reference fonts. Hence DIN is now applied as a baseline: for every character the differences between the testfonts (Tern, Transport, RWS) and the DIN fonts were computed. Therefore, RWS (A) was subtracted by DIN (A), Transport (B) by DIN (B) and Tern (C) by DIN (C). This computation has been accomplished for VMS and normal display separately. As a consequence, positive values stand for more correct answers in the test font than in the DIN font. On the other hand, negative values stand for less correct answers in comparison to the DIN font. Zero values point to equal values in DIN and test-typefaces.

[15] $difference_{normal}$=1.800; t[34]=6.643; p=0.000; $difference_{VMS}$=2.152; t[34]=7.673; $p < 0.01$

[16] difference=1.733; t[29]=5.666; p=0.000

Statistical analysis leads to the results that all key factors have significant effects[17]. They differ in distance, typeface and in the interaction of distance x typeface[18]. This means that typefaces behave very differently over the 3 distances (see Fig. 12, Fig. 13).

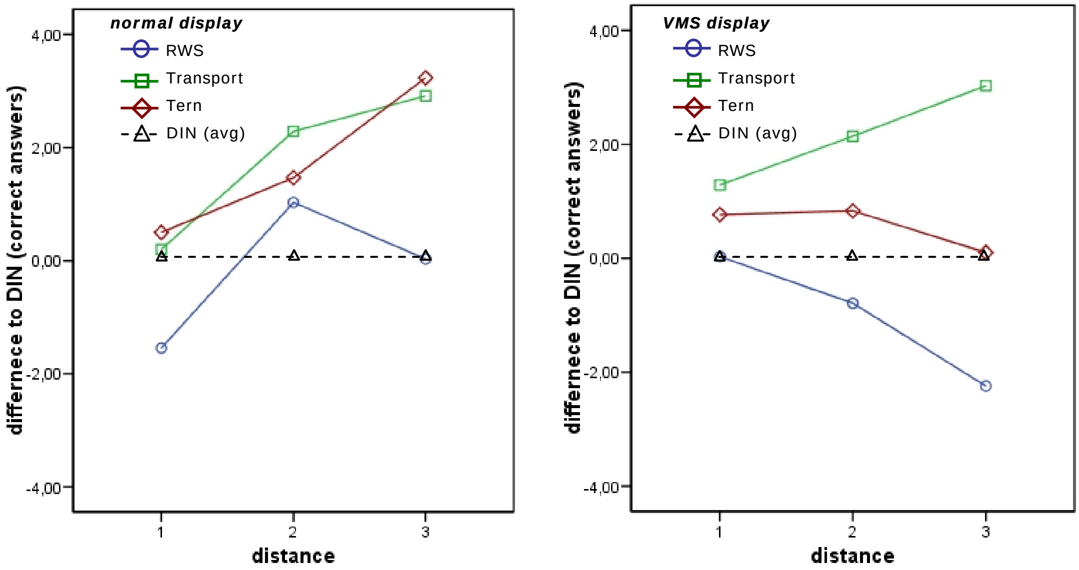


Fig. 12 (left hand side): Normal display: Comparison of the 3 testfonts, frequency of correct answers subtract DIN-fonts. The baseline DIN is averaged over the series A, B, C.

Fig. 13: (right hand side) VMS display: Comparison of the 3 testfonts, frequency of correct answers subtract DIN-fonts. The baseline DIN is averaged over the series A, B, C.

The differences in normal display between the three distances get significantly higher with increasing distance[19].

For VMS display, the difference between Transport and DIN is increasing while the difference between RWS and DIN is also increasing - though to the disadvantage of RWS. Tern shows similar results to DIN over the three distances[20].

For both display types, the effects of the typeface are meaningful, putting the “distance effect” aside. In normal display mode, correct answers in Transport and Tern turned out to be similar and are both more frequent than for RWS[21]. In VMS display, Transport has a higher score than Tern, followed by DIN, then RWS[22].

3.4. Error analysis

3.4.1. In-depth analysis of frequently mistaken characters

In this section, a detailed error analysis on the level of characters will be carried out (Fig. 14, Fig. 15). Data was averaged over three distances – the results were following sample sizes: RWS N=120 (3*40), Transport N=135 (4*45), Tern N=111, (3*37), DIN N=366 (3*122). The average over all characters corresponds to the results of the statistical report (see above).

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17 Normal distributed, homogeneous of covariances & error variances, Greenhouse-Geisser correction for normal display used

18 sign.main effect: series Pillai's Trace =0.564; F=18.655;df=4;Fehler df=190; p=0.000; sign. main effect. distance: Pillai's Trace (distance) =0.333; F=11.466; df=4; Fehler df=92; p=0.000; sign. interaction (series x distance): Pillai's Trace (series x distance)=.,246; F=3.265; df=8; Fehler df=186; p=0.002

19 effect of distance F[1,871]=17.187; p=0.000; no sign. interaction

20 interaction of distance F[4]=4.496; p=0.002; no sign. effect of distance

21 F[2]=14.539; p=0,000

22 F[2]=36.550; p=0,000

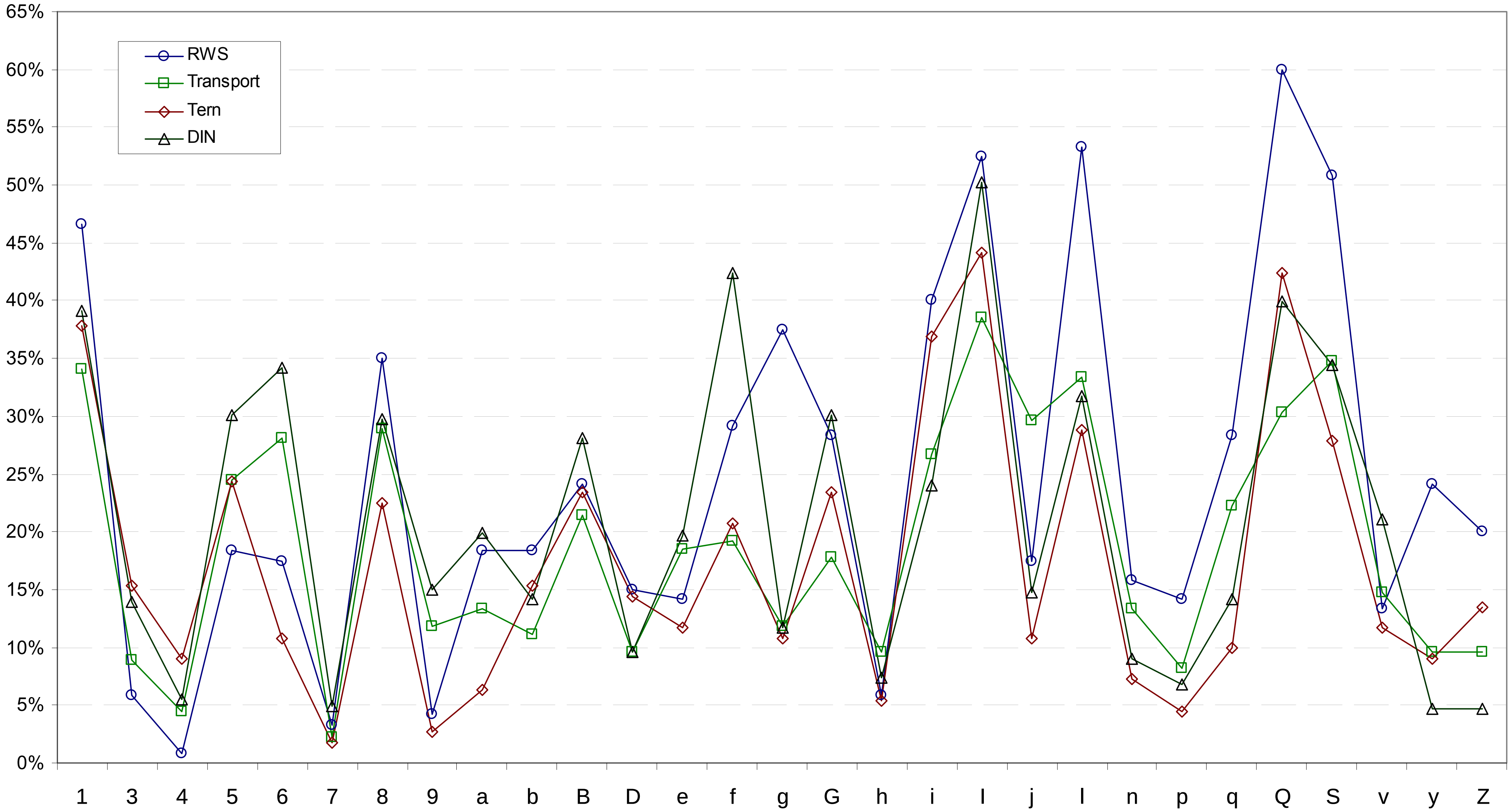


Fig. 14 Normal display mode: Percentage of subjects who mixed up one character with another (including errors concerning upper and lower cases).

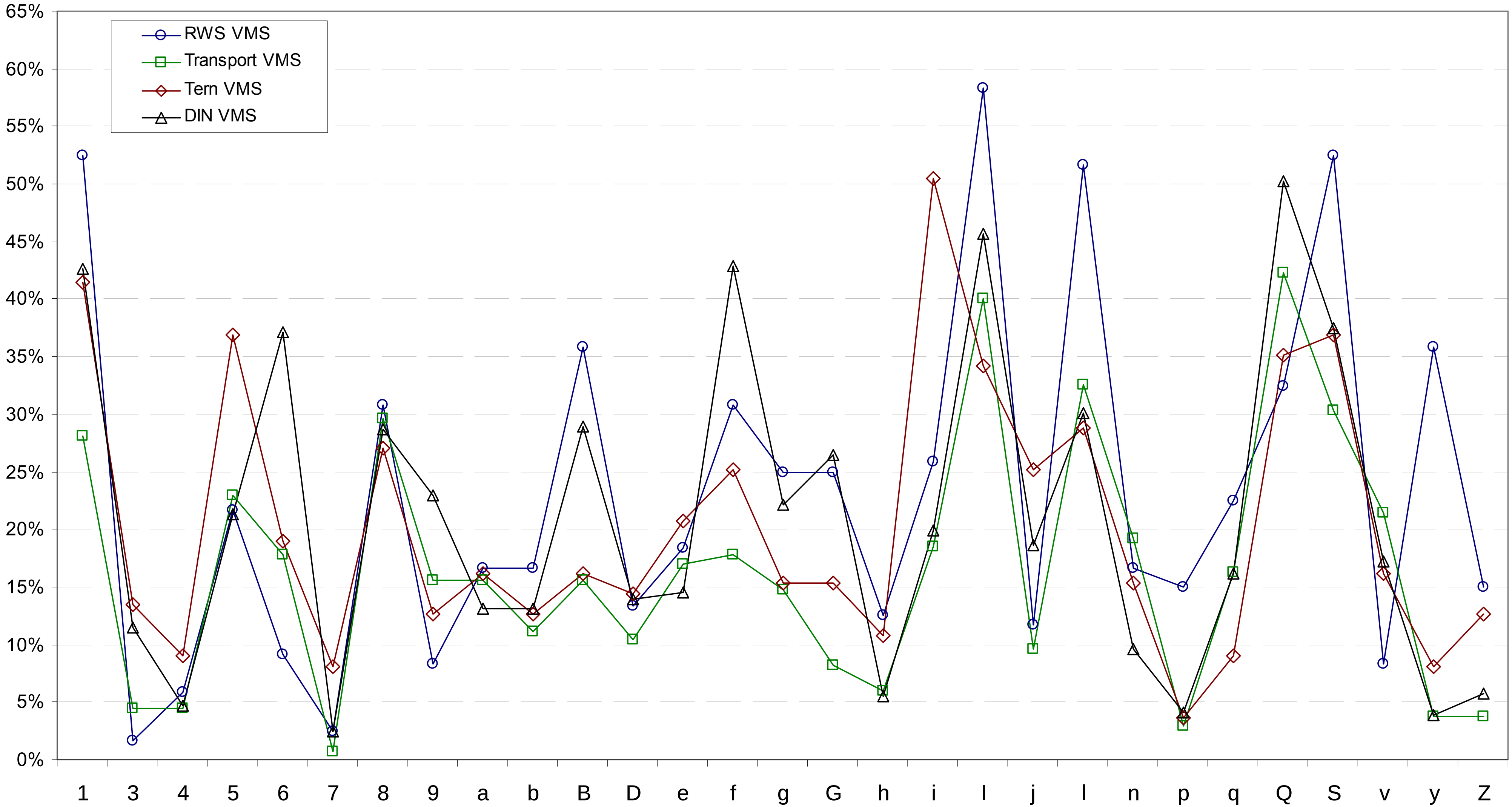


Fig. 15 VMS display –mode: Percentage of subjects who mixed up a character with another one (including errors concerning upper and lower cases).

In both versions the characters 1, f, i, I, l and j got mixed up, especially often among each other, further reciprocal confusion concerned the characters S - 5; G - 6; Q – O; 8 – B (whereas within the RWS-font the character 8 got confused with all sorts of other characters).

The shortcomings of the RWS-font particularly manifest in those confusions; above all the RWS provoked reading errors that were avoided by the other tested fonts: g – q (especially in *normal mode*); y – v (in *VMS-mode*).

The two fonts superior to the DIN-font (Transport and Tern) show similar mix-up-mistakes in *normal mode*. In *VMS-mode* particular problems concerning the Tern-font appeared: numerous confusions of i, l, 1, t, I and j, as well as 5 and S. The specific weakness of the Transport-font in *VMS-mode concerns* Q and O.[23]

3.4.2. Error rates of the most and least challenging characters

For this section a comparison between two different sets of characters has been carried out: the most challenging ("usual suspects", including some numbers) vs. the easier identifiable characters. Therefore the percentage of users who mixed up a specific character within the viewing distance 1 or 2 is reported. For this analysis, only data from Tern and DIN fonts were available.

In Fig. 16 the set of the difficult characters is depicted. The characters are ordered by DIN-font by increasing error rate. Hence the most challenging characters of the reference font are diagrammed on the right hand side.

[23] The occurrence of errors where small and large caps were mistaken are mainly uncommon (mean: 0.88%), except for I (19.7 % in RWS, between 7.4 and 12.3% for the other fonts); I (5.2% in Transport) and j (11.6% for RWS). The rest of this kind of errors are below 3%.

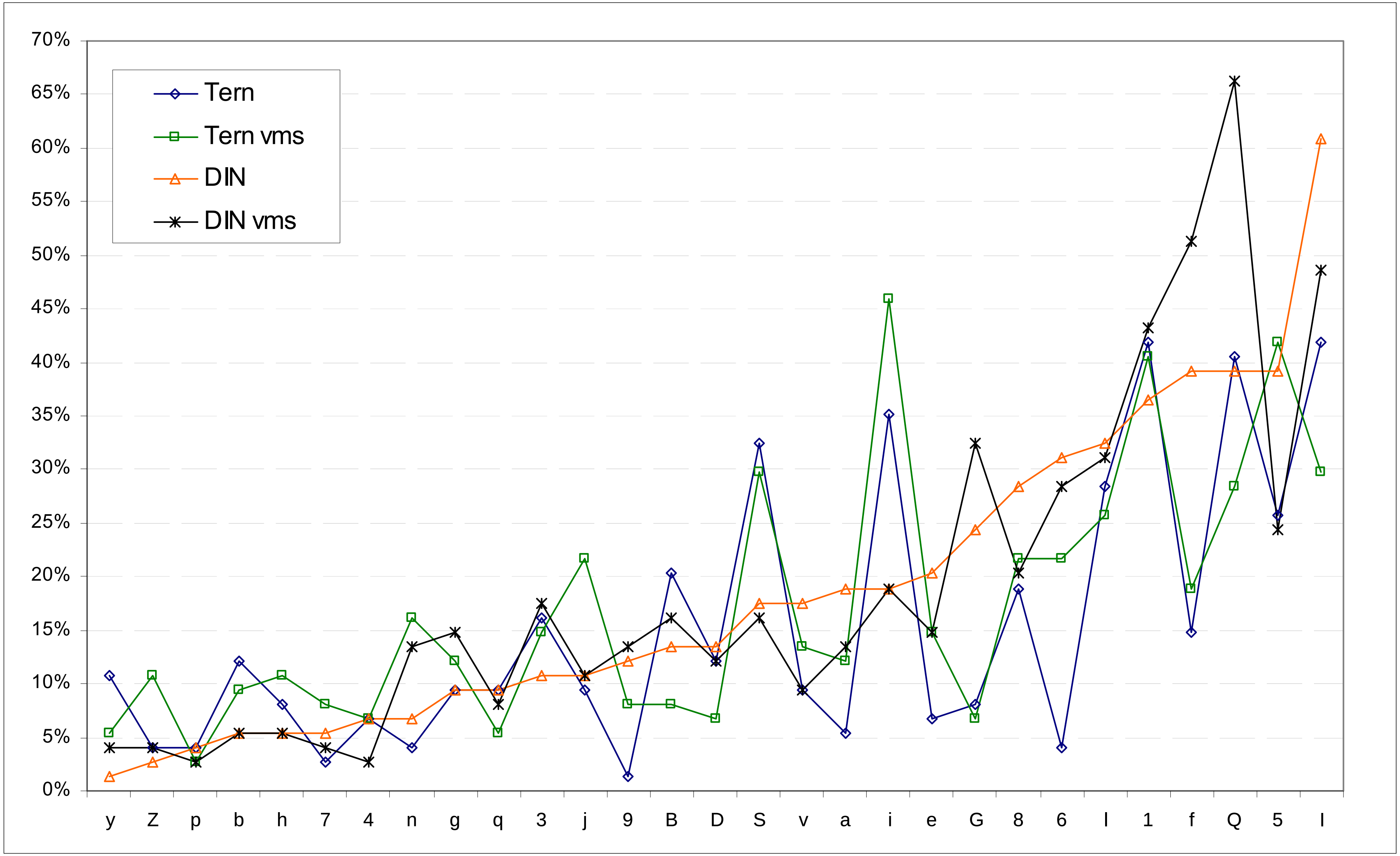


Fig. 16: Percentage of users who made mistakes within the most challenging set of characters (mean values for distance 1, 2; N=2*37, ordered by DIN).

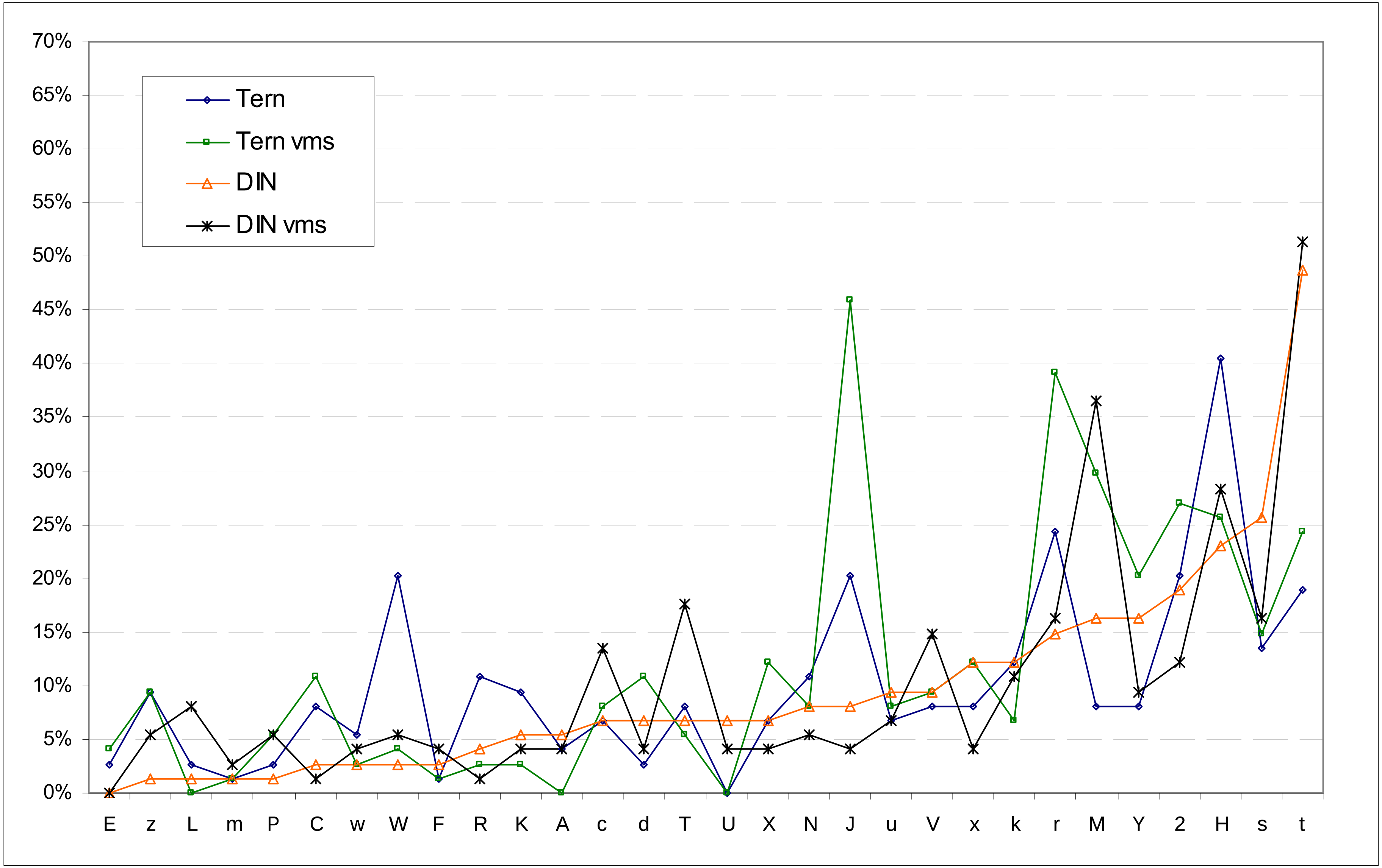


Fig. 17: Percentage of users who made mistakes within the "easier" set of characters (mean values for distance 1,2; N=2*37; ordered by DIN).

A lot of variation can be seen within fonts, especially DIN in VMS display (standard deviation of 14%) as well as within the characters (up to 18% by “J”). The most difficult characters were: 1, Q, I with mean error rates above 40% in all fonts and S, V, G, 8, 6, I, f, 5 with error rates above 25% in at least one font.

Fig. 17 shows the presumably easier identifiable set of characters: high error rates were detected for H, t above 25% in all fonts, for Tern-fonts 2, H, J, M and r, for DIN-fonts H, M, s und t[24].

		Tern	Tern VMS	DIN	DIN VMS
apriori - difficult set	mean	15.3%	17.2%	18.7%	19.1%
	std. dev.	12.6%	11.7%	14.4%	16.1%
apriori- easier set	mean	10.8%	13.9%	11.5%	11.2%
	std. dev.	8.6%	13.4%	11.4%	11.4%

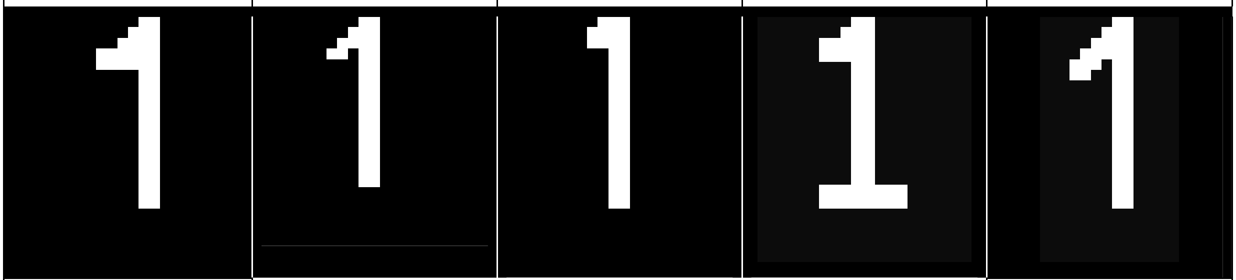
Table 11: Comparison of „usual suspects“ – the difficult characters and presumably easy to read characters (means and standard deviation).

Overall, although the mean errors look similar between the fonts (see Table 11), single characters offered huge differences: from 0 errors in E in both DIN-fonts up to 66% in Q for DIN in VMS display.
This empirically based compilation of the presented error analysis results gives a general overview which alphanumeric characters have room for improvement, also aside from ready-made “usual suspects”.

[24] Small and large caps are again rarely confused (mean: 0.85%), except for I (28.8 % in RWS, 9.4 for DIN and 13.3% for Transport); i (7.2% in Tern); j (5.8% for RWS) and S (5.0% for RWS). The rest of this kind of errors was lower than 3%. O and 0 have been excluded because these characters were identical for the typeface DIN.

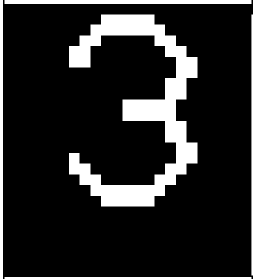
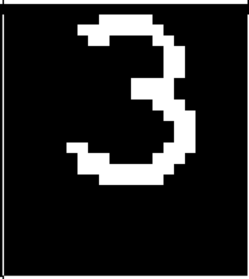
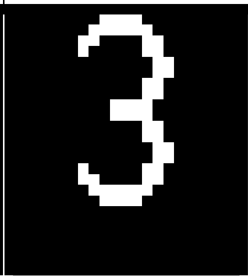
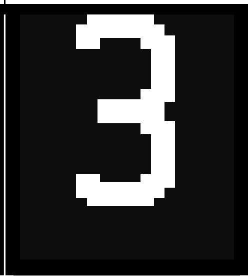
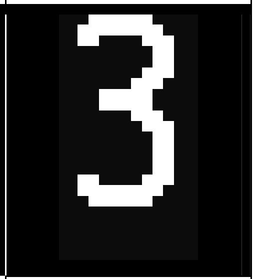
3.5. Single comparison and recommendations for redesign

Transport	RWS	DIN	Tern	Tern final
				
34,07%[25]	46,67%	39,07%	37,84%	
Analysis A distinctive arm has positive effect on discrimination, Serifs at the lower end of the stem do not seem to have influence.				

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
28,15%	52,50%	42,62%	41,44%	
Analysis A distinctive arm has positive effect on discrimination, Serifs at the lower end of the stem do not seem to have influence.				

Transport	RWS	DIN	Tern	Tern final
				
8,89%	5,83%	13,93%	15,32%	
Analysis The shape of the character should not be to closed, nor to open. It is recommended to use a lower curve being larger than the upper, and only a short stroke were the curves meet.				

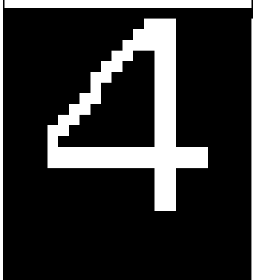
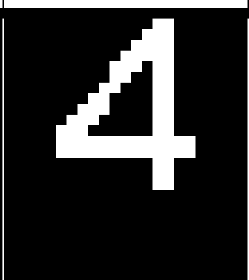
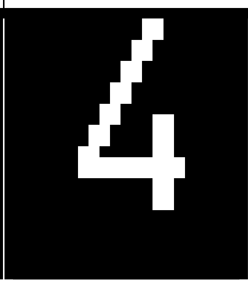
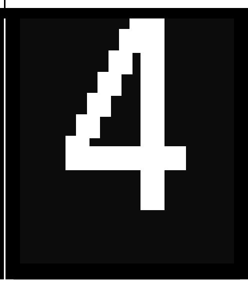
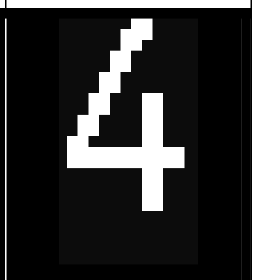
[25] error rates , see previous section, Fig. 14, Fig. 15

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
4,44%	1,67%	11,48%	13,51%	

Analysis The shape of the character should not be to closed, nor to open. A lower curve being larger than the upper, and only a short stroke were the curves meet is recommended. For matrix display, it is additionally important for the curves to be clearly recognizable bends.

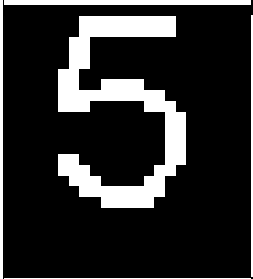
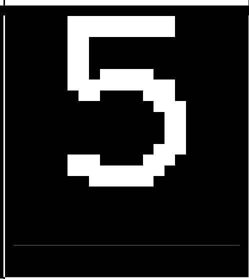
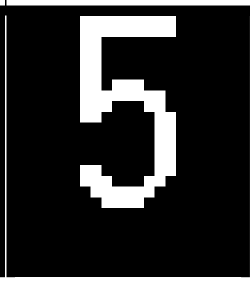
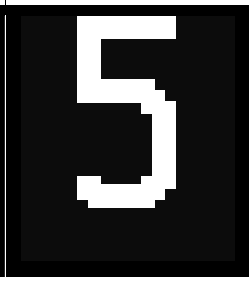
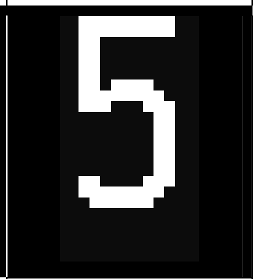
Transport	RWS	DIN	Tern	Tern final
				
4,44%	0,83%	5,46%	9,01%	

Analysis The diagonal stroke should tend towards a 45 degree angle to make 4 easily discriminable, an open form (stroke and stem should not connect) helps to support this with less wide typefaces.

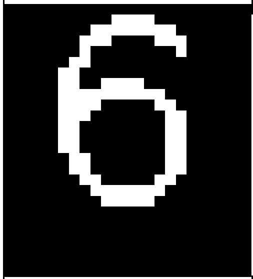
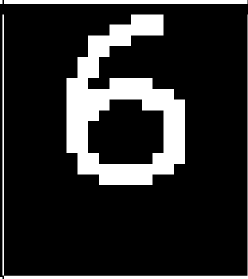
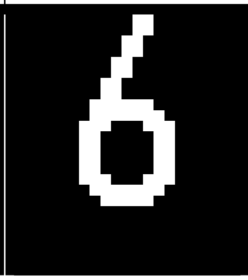
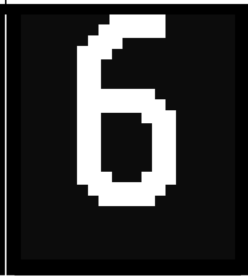
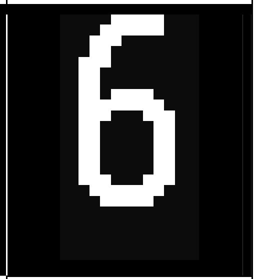
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
4,44%	5,83%	4,64%	9,01%	

Analysis The diagonal stroke needs to tend towards an acute angle to make 4 easily discriminable, an open form (stroke and stem don't connect) helps to support this with less wide typefaces.

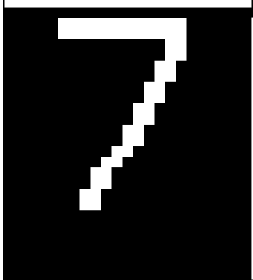
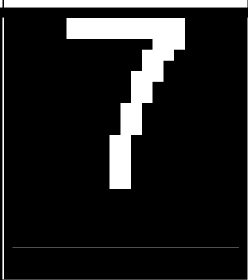
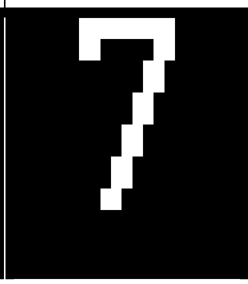
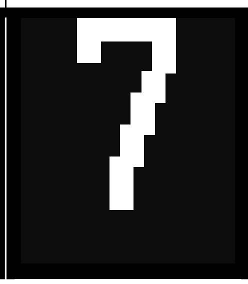
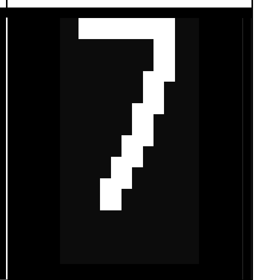
Transport	RWS	DIN	Tern	Tern final
				
24,44%	18,33%	30,05%	24,32%	
Analysis	Again, the lower curve needs to be distinctively bent and round, but the aperture should not be too closed.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
22,96%	21,67%	21,31%	36,94%	
Analysis	Again, the lower curve needs to be distinctively bent and round, but the aperture should not be too closed.			

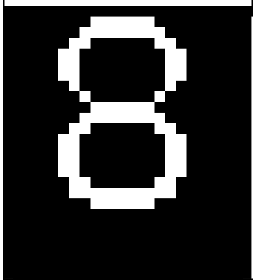
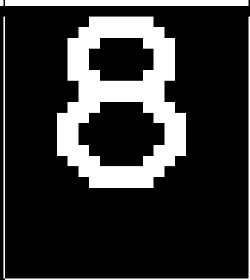
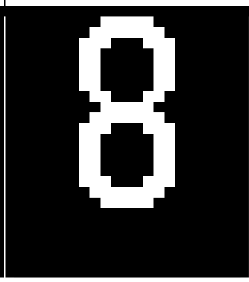
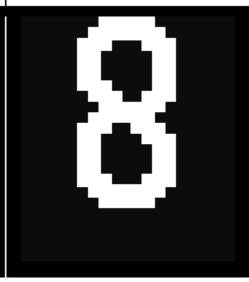
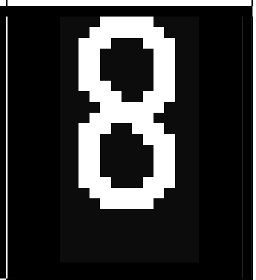
Transport	RWS	DIN	Tern	Tern final
				
28,15%	17,50%	34,15%	10,81%	
Analysis	The stroke extending to the top has to be clearly bent, the character should not bear any straight lines, aperture clear and not too closed.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
17,78%	9,17%	37,16%	18,92%	
Analysis	The stroke extending to the top has to be clearly bent, the character should not bear any straight lines, aperture clear and not too closed.			

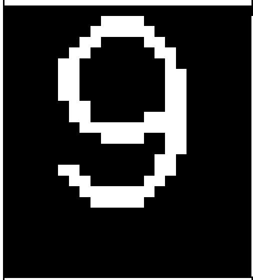
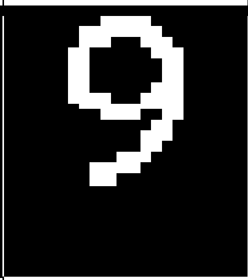
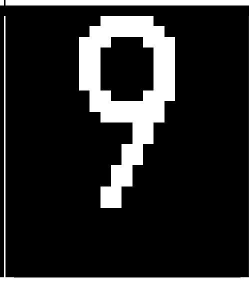
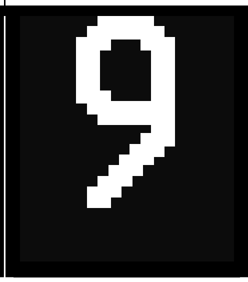
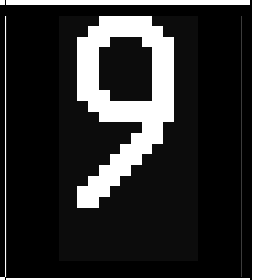
Transport	RWS	DIN	Tern	Tern final
				
2,22%	3,33%	4,92%	1,80%	
Analysis	The stroke should be oblique and straight, extending far to the left hand side at the base. The serif in DIN VMS does not seem to have any effect.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
0,74%	2,50%	2,46%	8,11%	
Analysis	The stroke should be oblique and straight, extending far to the left hand side at the base. The serif in DIN VMS does not seem to have any effect.			

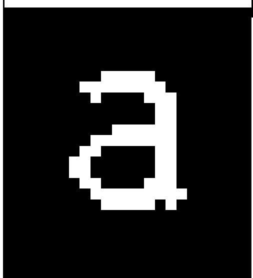
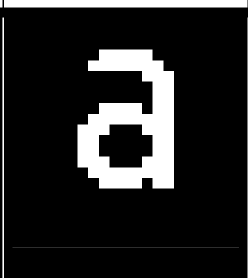
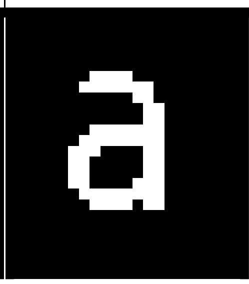
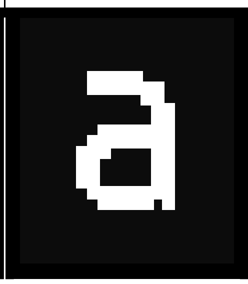
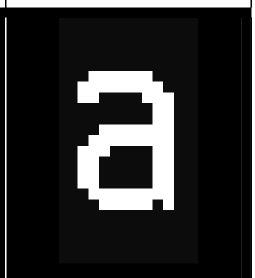
Transport	RWS	DIN	Tern	Tern final
				
28,89%	35,00%	29,78%	22,52%	
Analysis	Performance depends on discriminable counters and an as-thin-as-possible "waist", which need to be clear to distinct from characters as B, S or O and others, which is why the character "8" should not be to wide.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
29,63%	30,83%	28,69%	27,03%	
Analysis	Performance depends on discriminable counters and an as-thin-as-possible "waist", which need to be clear to distinct from characters as B, S or O and others, which is why the character "8" should not be to wide.			

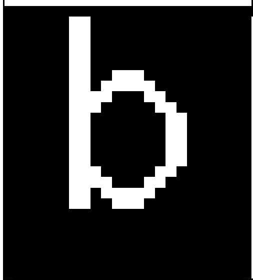
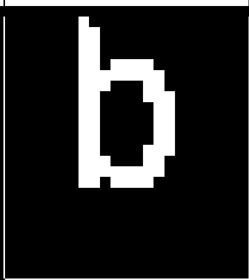
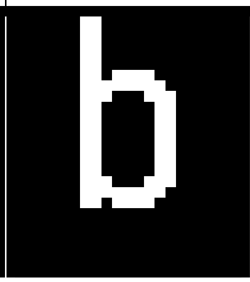
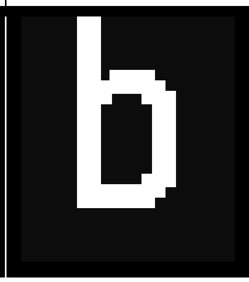
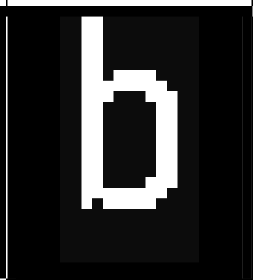
Transport	RWS	DIN	Tern	Tern final
				
11,85%	4,17%	15,03%	2,70%	
Analysis	As with 6, there is a preference for a character without straights. The tail should be well inclined, to reach far to the left at the base, and not bent too much to allow for a very open aperture.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
15,56%	8,33%	22,95%	12,61%	
Analysis	As with 6, there is a preference for a character without straights. The tail should be well inclined, to reach far to the left at the base, and not bent too much to allow for a very open aperture.			

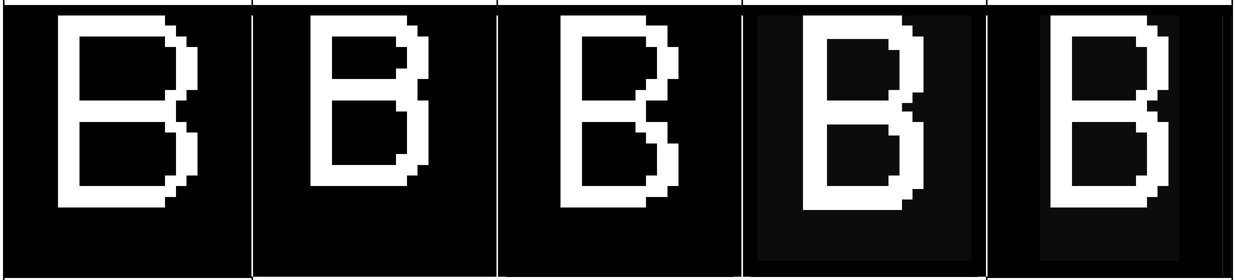
Transport	RWS	DIN	Tern	Tern final
				
13,33%	18,33%	19,95%	6,31%	
Analysis	Counter and aperture are to be clear and balanced.			

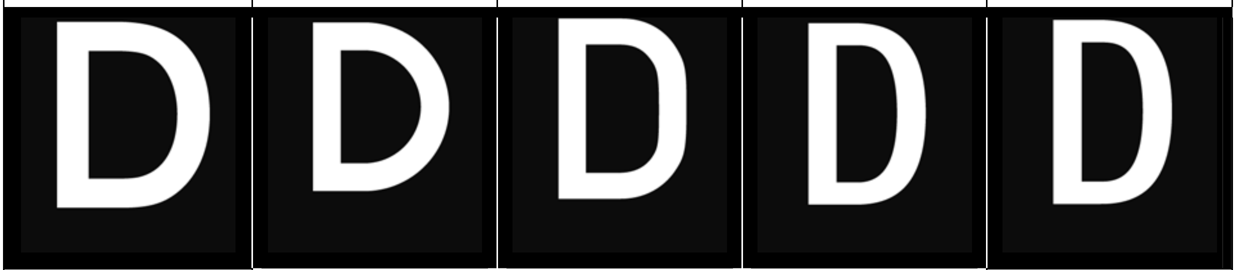
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
15,56%	16,67%	13,11%	16,22%	
Analysis	Counter and aperture are to be clear and balanced. In VMS display, the bowl needs to be clearly recognized as being round.			

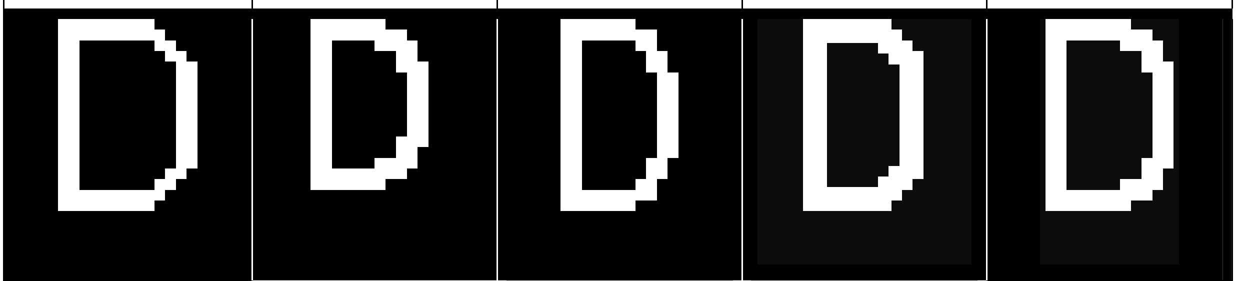
Transport	RWS	DIN	Tern	Tern final
				
11,11%	18,33%	14,21%	15,32%	
Analysis	Ascending part of the stem to be long enough to be distinguished from the bowl which seems to be best discriminable when close to being ovoid. Inclined cut-offs to a stem´s ending are not recommended.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
11,11%	16,67%	13,11%	12,61%	
Analysis	Ascending part of the stem to be long enough to be distinguished from the bowl which seems to be best discriminable when close to being ovoid. Inclined cut-offs to a stem´s ending are not recommended.			

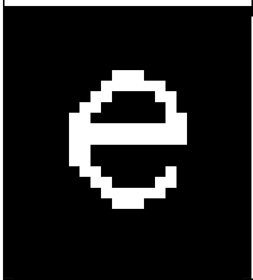
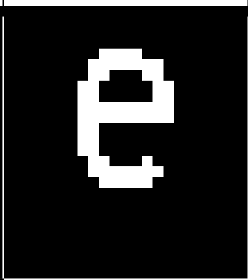
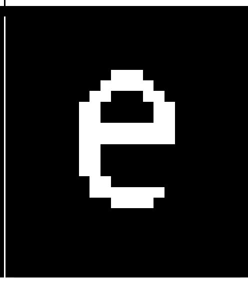
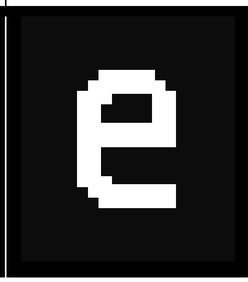
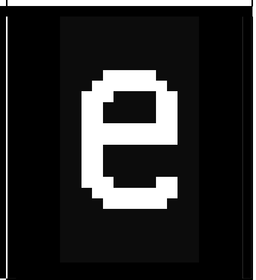
Transport	RWS	DIN	Tern	Tern final
				
21,48%	24,17%	28,14%	23,42%	
Analysis	Upper and lower bowl should not be identical; it is advisable to articulate the lower bowl wider/higher than the upper.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
15,56%	35,83%	28,96%	16,22%	
Analysis	Upper and lower bowl should not be identical; it is advisable to articulate the lower bowl wider/higher than the upper.			

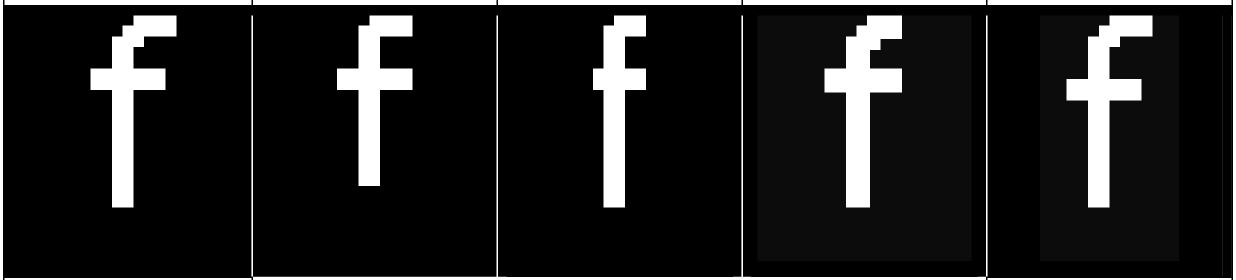
Transport	RWS	DIN	Tern	Tern final
				
9,63%	15,00%	9,56%	14,41%	
Analysis	With this character, a preference for a wide letter is clear. In addition it seems appropriate not to design the bowl like a fraction of a circle; its bend should rather bear a more horizontal motion, or be straight on the part in the middle.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
10,37%	13,33%	13,93%	14,41%	
Analysis	With this character, a preference for a wide letter is clear. In addition it seems appropriate not to design the bowl like a fraction of a circle; its bend should rather bear a more horizontal motion, or be straight on the part in the middle.			

Transport	RWS	DIN	Tern	Tern final
				
18,52%	14,17%	19,67%	11,71%	
Analysis	Aperture to be wide open and balanced with a wide, distinctive eye.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
17,04%	18,33%	14,48%	20,72%	
Analysis	Aperture to be wide open and balanced with a wide, distinctive eye.			

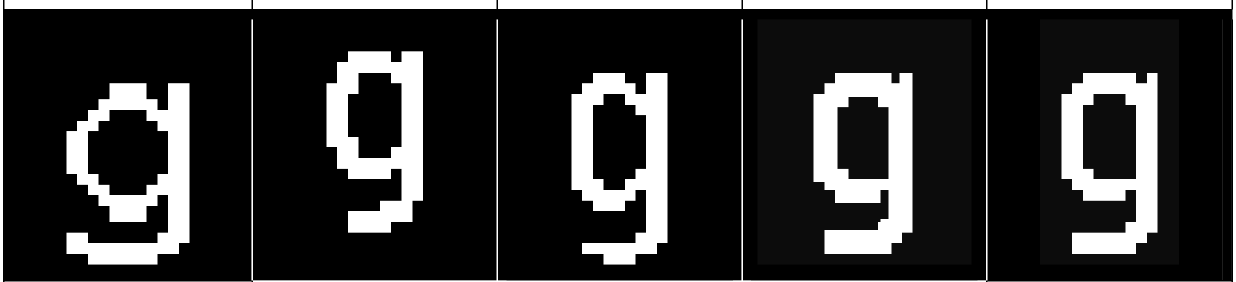
Transport	RWS	DIN	Tern	Tern final
				
19,26%	29,17%	42,35%	20,72%	
Analysis	Performance is depending on the distinctiveness of features which separate the letter from other stem-reliant characters. The arm should extend further to the right than the cross-stroke, which should be placed in considerable distance to the arm to allow for enough space in between.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
17,78%	30,83%	42,90%	25,23%	

Analysis Performance is depending on the distinctiveness of features which separate the letter from other stem-reliant characters. The arm should extend further to the right than the cross-stroke, which should be placed in considerable distance to the arm to allow for enough space in between.

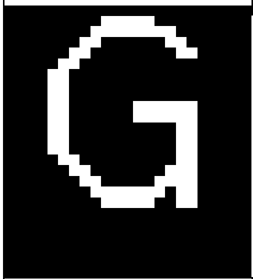
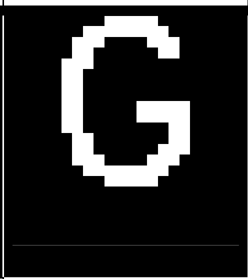
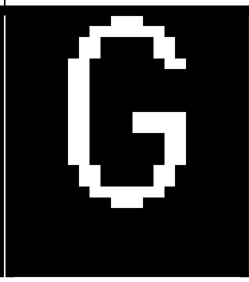
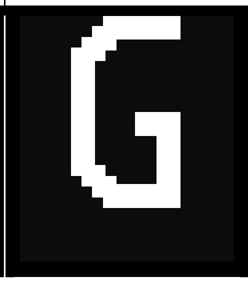
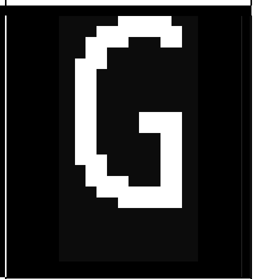
Transport	RWS	DIN	Tern	Tern final
				
11,85%	37,50%	11,75%	10,81%	

Analysis Counter and aperture to be distinctive and balanced, which can be achieved by reducing the x-height in favour of the descending tail, as shown in Tern. A cut-off tail should be avoided.

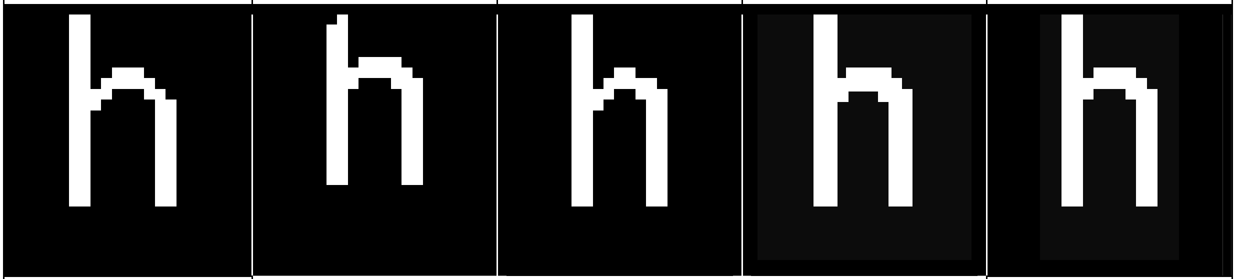
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
14,81%	25,00%	22,13%	15,32%	

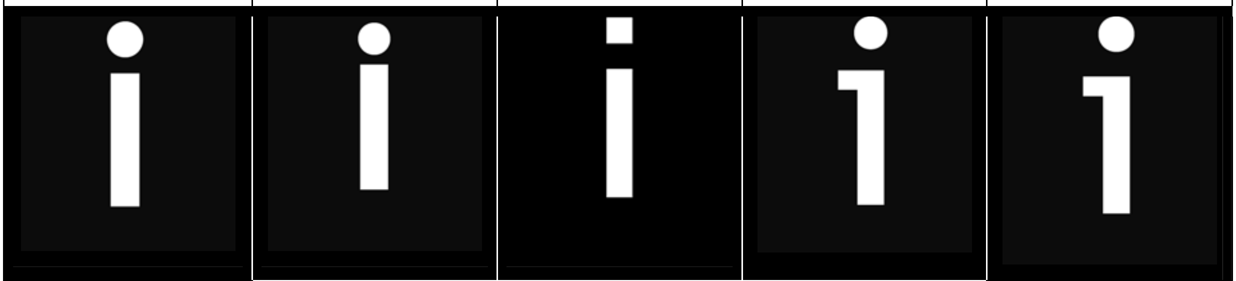
Analysis Counter and aperture to be distinctive and balanced, which can be achieved by reducing the x-height in favour of the descending tail, as shown in Tern. A cut-off tail should be avoided.

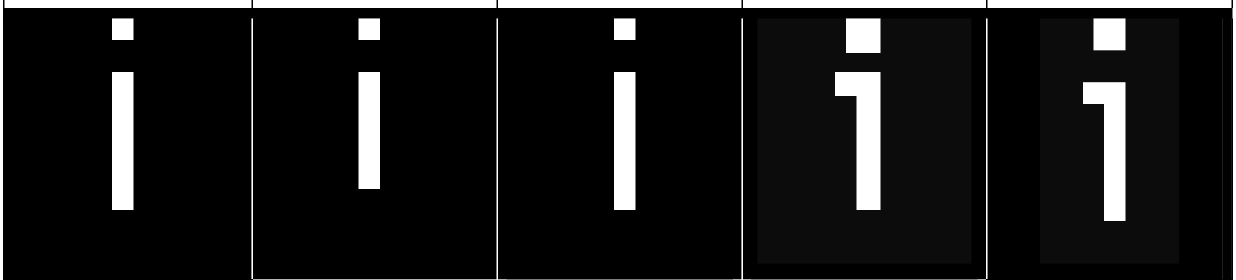
Transport	RWS	DIN	Tern	Tern final
				
17,78%	28,33%	30,05%	23,42%	
Analysis	Aperture should be wide open; the chin should be placed in the vertical middle of the letter.			

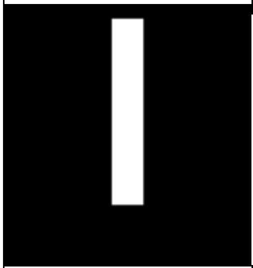
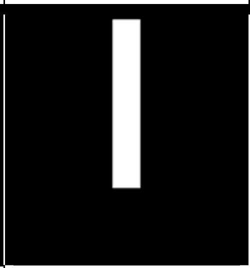
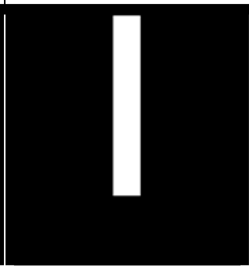
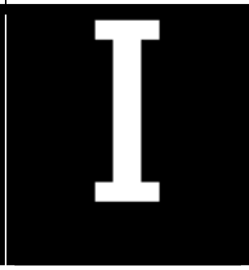
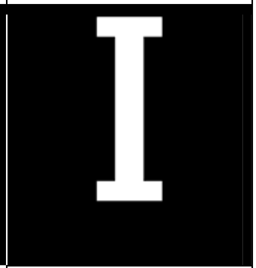
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
8,15%	25,00%	26,50%	15,32%	
Analysis	Aperture should be wide open; the chin should be placed in the vertical middle of the letter.			

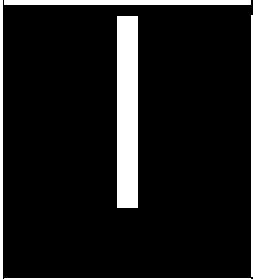
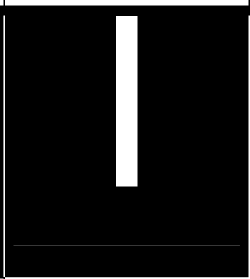
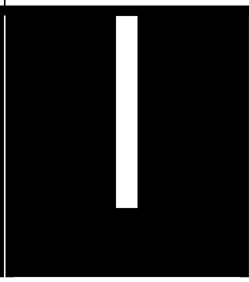
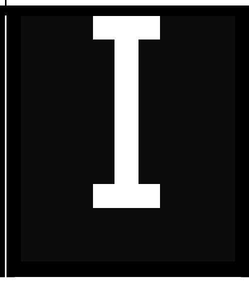
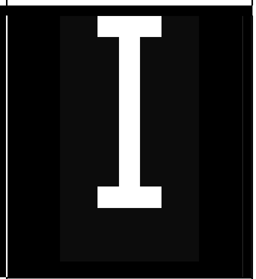
Transport	RWS	DIN	Tern	Tern final
				
9,63%	5,83%	7,38%	5,41%	
Analysis	A character which is easy to discriminate.			

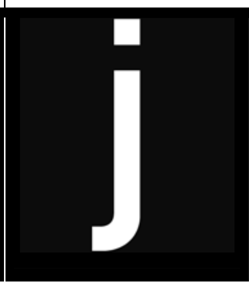
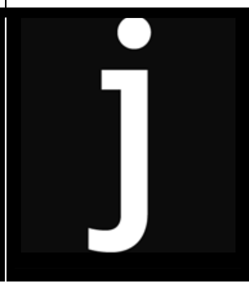
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
5,93%	12,50%	5,46%	10,81%	
Analysis	A character which is easy to discriminate. Inclined cut-offs from the top of the stem might enhance the possibility of confusion with the letter n. There seems to be a preference for a link having a "steep" angle to allow for the bow to be more distinctively set off the stem.			

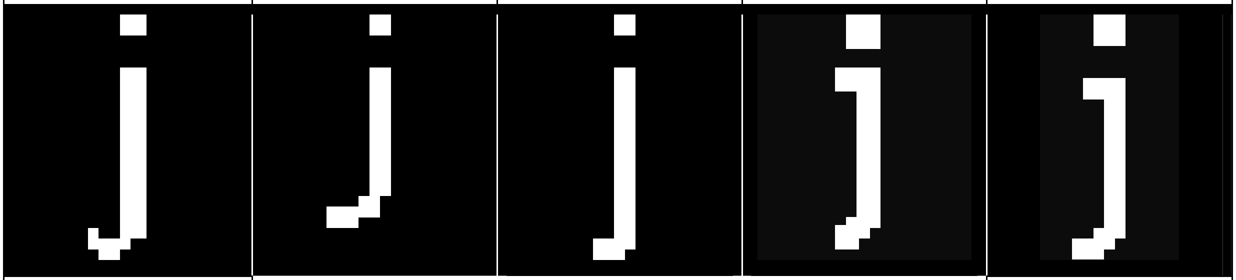
Transport	RWS	DIN	Tern	Tern final
				
26,67%	40,00%	24,04%	36,94%	
Analysis	The negative space between the stem and the dot must be wide to allow for good distinction from characters as I, f, l, 1, … The influence of a serif is to be explored in further testing.			

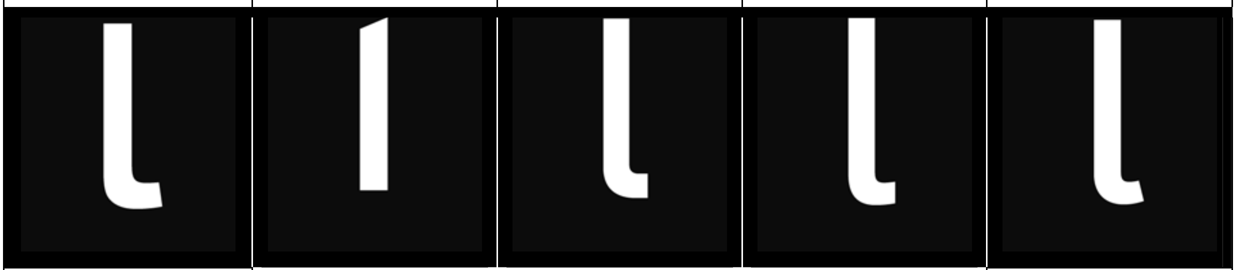
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
18,52%	25,83%	19,95%	50,45%	
Analysis	The negative space between the stem and the dot must be wide to allow for good distinction from characters as I, f, l, 1, … The influence of a serif is to be explored in further testing.			

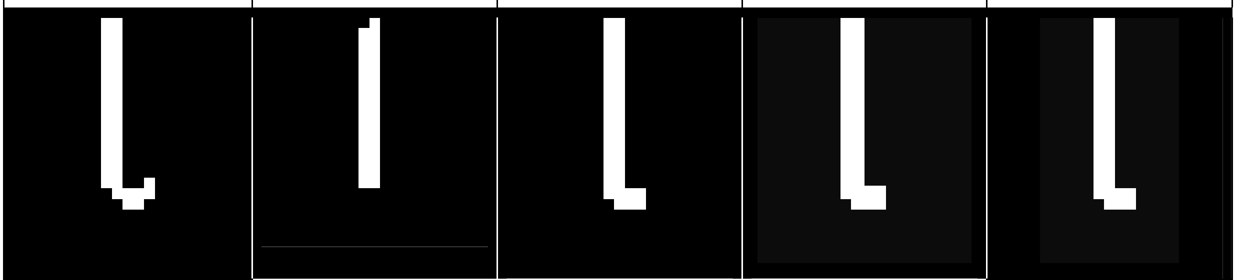
Transport	RWS	DIN	Tern	Tern final
				
38,52%	52,50%	50,27%	44,14%	
Analysis	A very high possibility for confusion with i, +, 1, t, I – it is advised to add serifs for distinction on top and base.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
40,00%	58,33%	45,63%	34,23%	
Analysis	A very high possibility for confusion with i, +, 1, t, I – it is advised to add serifs for distinction on top and base.			

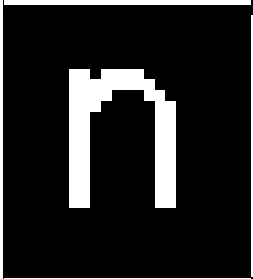
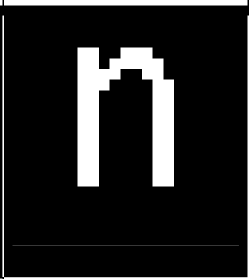
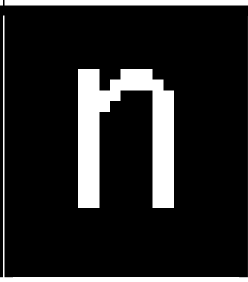
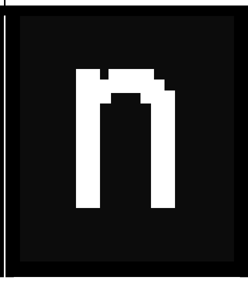
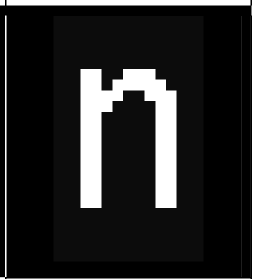
Transport	RWS	DIN	Tern	Tern final
				
29,63%	17,50%	14,75%	10,81%	
Analysis	As with i, the distance between stem and dot must be large, while the tail is needed to be considerably bent and wide.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
9,63%	11,67%	18,58%	25,23%	
Analysis	As with i, the distance between stem and dot must be large, while the tail is needed to be considerably bent and wide.			

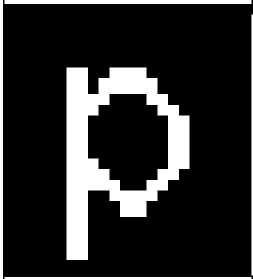
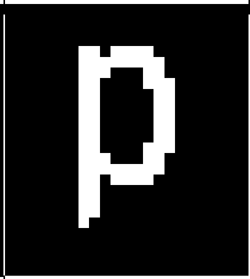
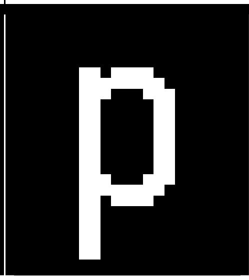
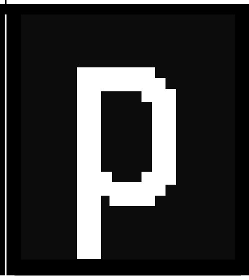
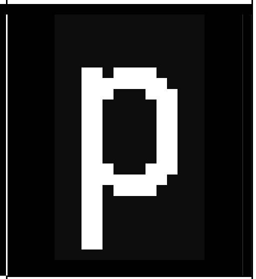
Transport	RWS	DIN	Tern	Tern final
				
33,33%	53,33%	31,69%	28,83%	
Analysis	It is of great importance to employ a bent terminal here to distinct from other characters.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
32,59%	51,67%	30,05%	28,83%	
Analysis	It is of great importance to employ a bent terminal here to distinct from other characters.			

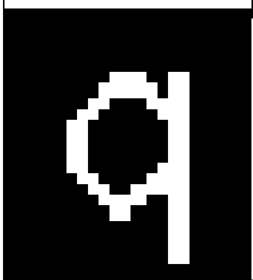
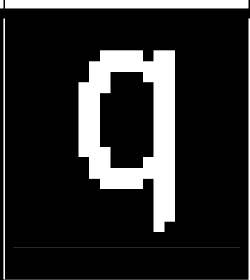
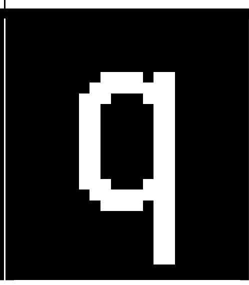
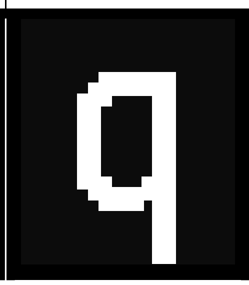
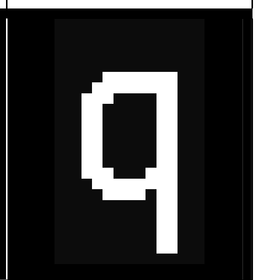
Transport	RWS	DIN	Tern	Tern final
				
13,33%	15,83%	9,02%	7,21%	
Analysis	The stem has to be clearly discriminable as a vertical line. To achieve this, the link should have a steep angle to clearly distinct the stem from the curve.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
19,26%	16,67%	9,56%	15,32%	
Analysis	The stem has to be clearly discriminable as a vertical line. To achieve this, the link should have a steep angle to clearly distinct the stem from the curve.			

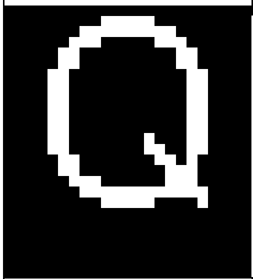
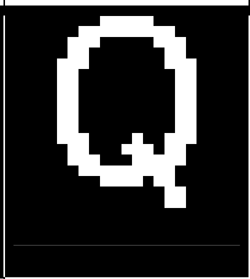
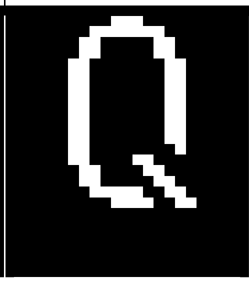
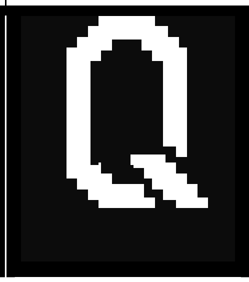
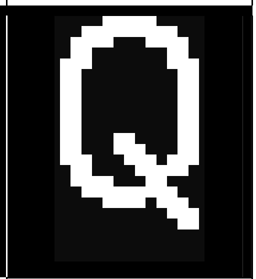
Transport	RWS	DIN	Tern	Tern final
				
8,15%	14,17%	6,83%	4,50%	
Analysis	Too short descending tails lead to confusion with other characters. For a sufficient length, the x-height is reduced in favour of the descender.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
2,96%	15,00%	4,10%	3,60%	
Analysis	Too short descending tails lead to confusion with other characters. For a sufficient length, the x-height is reduced in favour of the descender.			

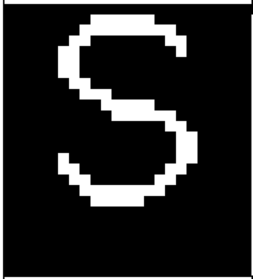
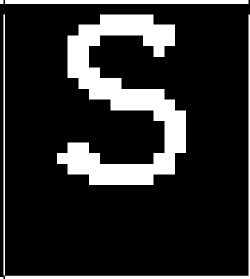
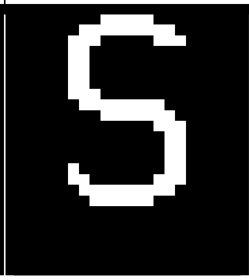
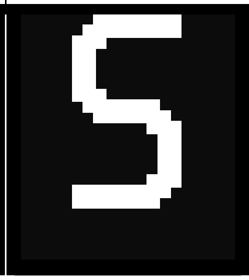
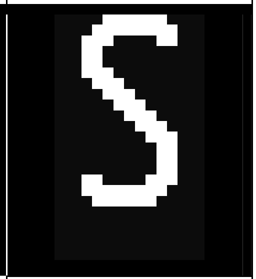
Transport	RWS	DIN	Tern	Tern final
				
22,22%	28,33%	14,21%	9,91%	
Analysis	Too short descending tails lead to confusion with other characters. For a sufficient length, the x-height is reduced in favour of the descender.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
16,30%	22,50%	16,12%	9,01%	
Analysis	Too short descending tails lead to confusion with other characters. For a sufficient length, the x-height is reduced in favour of the descender.			

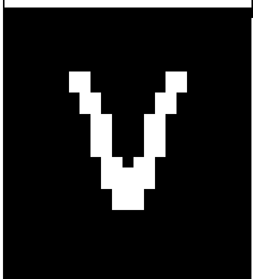
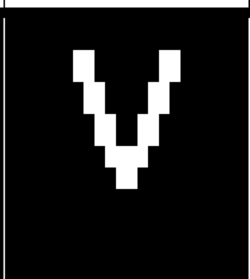
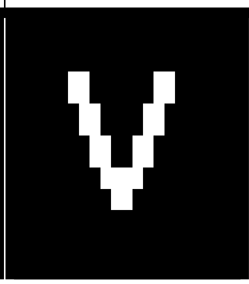
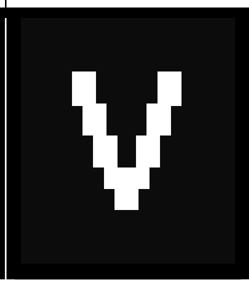
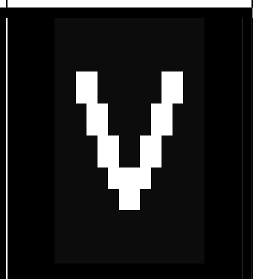
Transport	RWS	DIN	Tern	Tern final
				
30,37%	60,00%	39,89%	42,34%	
Analysis	The tail should cross the stroke and be distinctive. This is achieved by using descender space for the tail. Shadow lines do not enhance discrimination.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
42,22%	32,50%	50,27%	35,14%	
Analysis	The tail should cross the stroke and be distinctive. This is achieved by using descender space for the tail. Shadow lines do not enhance discrimination.			

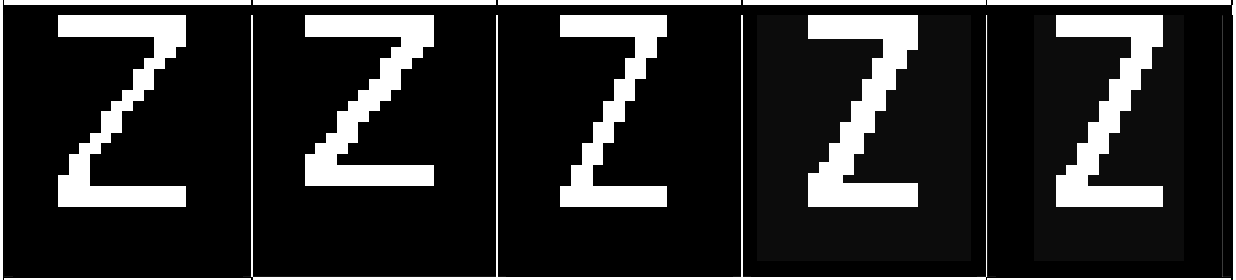
Transport	RWS	DIN	Tern	Tern final
				
34,81%	50,83%	34,43%	27,93%	
Analysis	Apertures need to be wide, but a wide character does not seem to be of advantage.			

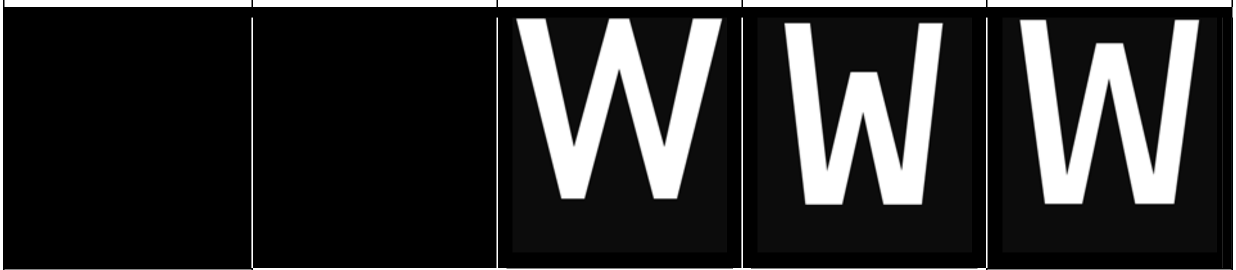
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
30,37%	52,50%	37,43%	36,94%	
Analysis	It seems that a horizontal line, formed at the meeting point of the curves should be avoided.			

Transport	RWS	DIN	Tern	Tern final
				
14,81%	13,33%	21,04%	11,71%	
Analysis	Performance is governed by the similarity of a font's other characters. Improvement seems to be possible by increasing the negative space to give it a more distinctive v-shape.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
21,48%	8,33%	17,21%	16,22%	
Analysis	Performance is governed by the similarity of a font's other characters. Improvement seems to be possible by increasing the negative space to give it a more distinctive v-shape. Curved lines should be avoided.			

Transport	RWS	DIN	Tern	Tern final
				
9,63%	20,00%	4,64%	13,51%	
Analysis	A wide character does not necessarily improve discrimination.			

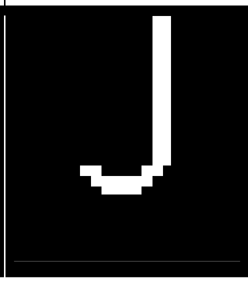
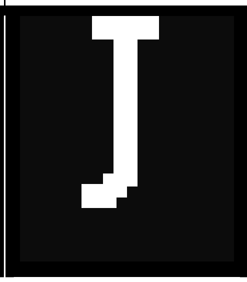
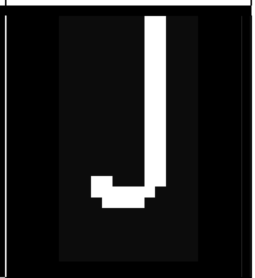
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
3,70%	15,00%	5,74%	12,61%	
Analysis	A wide character does not necessarily improve discrimination.			

Transport	RWS	DIN	Tern	Tern final
				
		2,70%[26]	20,27%	
Analysis	Negative space must be wide enough to clearly distinct its v-shapes. The apex of the two strokes in the middle should be positioned high to clarify the A-shape of the negative space underneath.			

[26] error rates , see previous section Fig. 16, Fig. 17

Transport	RWS	DIN	Tern	Tern final
				
		8,11%	20,27%	

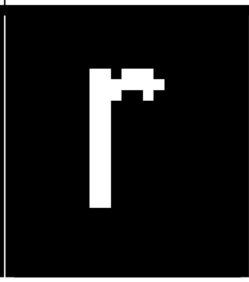
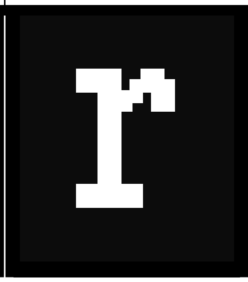
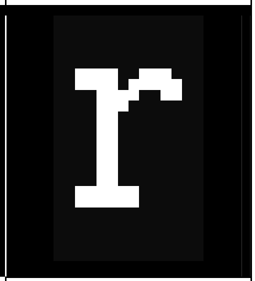
Analysis Serifs on top of the characters stem obstruct discrimination, while a wide and bent terminal has a positive effect.

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		4,05%	45,95%	

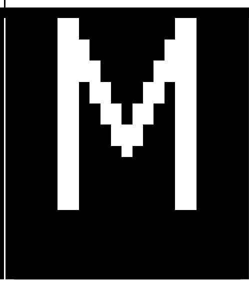
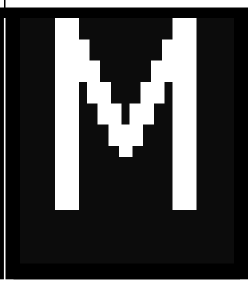
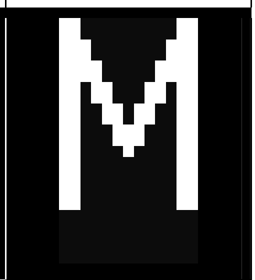
Analysis Serifs on top of the characters stem obstruct discrimination, while a wide and bent terminal has a positive effect.

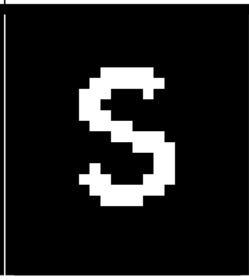
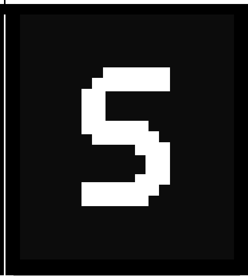
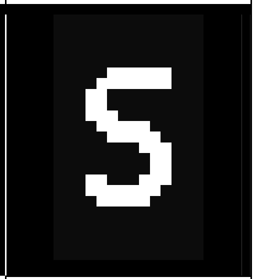
Transport	RWS	DIN	Tern	Tern final
				
		14,86%	24,32%	

Analysis The arm should bear a wide, bent shape, and it has to be able to allow for clear distinction from the stem. The influence of serifs is to be evaluated in further studies.

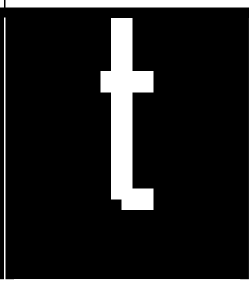
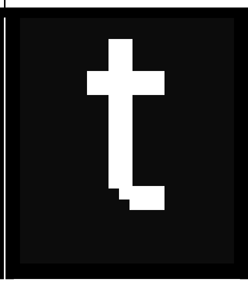
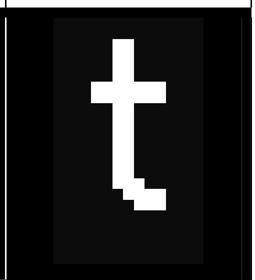
Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		16,22%	39,19%	
Analysis	The arm should bear a wide, bent shape, and it has to be able to allow for clear distinction from the stem. The influence of serifs is to be evaluated in further studies.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		16,22%	8,11%	
Analysis	Negative space above and below the joining strokes should be well balanced to allow for clear discrimination of their shapes.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		36,49%	29,73%	
Analysis	Negative space above and below the joining strokes should be well balanced to allow for clear discrimination of their shapes.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		16,22%	14,86%	
Analysis	Since the character’s size does not implicate confusion with 5, it is possible to employ straight horizontal lines as terminals to allow for open aperture-shapes.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		48,65%	18,92%	
Analysis	Horizontal features have to be wide, and the terminal is needed to have a considerable curve.			

Transport VMS	RWSVMS	DIN VMS	Tern VMS	Tern VMS final
				
		51,35%	24,32%	
Analysis	Horizontal features have to be wide, and the terminal is needed to have a considerable curve.			

4. Discussion and Conclusions

As the entire structure of the legibility test was aligned with the leading question of maximum legibility and the task of further optimization the conclusions drawn from the results are also discussed from the practical point of view. The comparative study of three existing traffic-sign-fonts and one newly designed set of characters showed some remarkable differences in regard to their general legibility as well as to their ability to compensate the typical reading errors generated by "usual suspects" of problematic characters.

Under the extended testing conditions of *impaired visibility* and *dual-purpose-display-mode* (*normal* and *VMS*) an empirically grounded legibility-ranking had been established. A general decline in legibility could be uncovered from *Transport* to *Tern*, followed by *DIN* and the *RWS*-font for VMS displayed typefaces.

Following up to that general analysis a specific examination of difficult characters took place that actually delivered a good deal of concrete design- and optimization-recommendations for the newly developed font Tern.

As expected, there seems to be an advantage for wide characters, but specific exceptions found in evaluation make a clear suggestion for a more sophisticated approach to typeface design.

The following issues were identified during evaluation of these test´s results which are proposed for further testing and evaluation:

- The influence on discrimination of serifs employed on the characters 1,i, j, J and r
- The size of serifs
- The possibility of straight, horizontal terminals in the lower case s
- Using x-height in favour of a greater negative space between dot and stem in i and j
- The 45 degree angle straight stroke connecting the two bows of S.

The successful iterative design of the European traffic typeface *Tern* emphasises that the chosen approach enhances the design process of typeface characters. Nevertheless there are some methodological issues to improve like the optimisation of viewing distances to make testing a less demanding task (0,65 or 0,5 visual acuity) and improvements concerning the selection of characters to test, which should be taken into account for further research.

Regarding the enhancement of road safety information systems the following conclusions could be drawn upon the recommendations of the shortcomings:

- As to new developments of traffic systems and environments an evaluation of applied typefaces should be mandatory. The harmonisation of an uniform typeface-standard should be emphasised as the study shows significant differences within the legibility of existing typefaces used.
- Integrating the user participation during the design process proved to be useful to identify shortcomings of the present font design, generate new ideas and hypothesis and re-check existent assumptions.
- Further research questions should cover investigations on the road (e.g. observation of driver behaviour), research on readability above the character level (words) and the impact on legibility by the systematic variation of specific typographic design elements (graphemic cues).

Apart from those recommendations, the close research-cooperation of designers and evaluators turned out to be very effective in terms of integrating the shortcomings and taking the results to account. The conducted testseries and analysis lead to design-advancements and -optimizations of the Tern-font.

5. Figures and Tables

6. References

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7. Attachments

7.1. ANOVA Results: Paired comparisons

Type-face	(I) series	(J) series	mean difference (I-J)	standard error	p (a)	95% Confidence Interval	
						lower limit	upper limit
normal display	A	B	-1.962(*)	0.407	.000	-2.953	-0.971
		C	-1.895(*)	0.423	.000	-2.925	-0.865
	B	A	1.962(*)	0.407	.000	0.971	2.953
		C	0.067	0.417	1.000	-.950	1.083
	C	A	1.895(*)	0.423	.000	0.865	2.925
		B	-0.067	0.417	1.000	-1.083	0.950
VMS display	A	B	-3.152(*)	0.369	.000	-4.051	-2.254
		C	-1.567(*)	0.383	.000	-2.501	-0.632
	B	A	3.152(*)	0.369	.000	2.254	4.051
		C	1.586(*)	0.378	.000	0.664	2.507
	C	A	1.567(*)	0.383	.000	0.632	2.501
		B	-1.586(*)	0.378	.000	-2.507	-0.664

* significant differences in means

a Bonferroni adaption.

7.2. Final TERN – normal version

Fig. 18 The final "Tern" typeface (normal version) available from IIID.

7.3. Final TERN – VMS version

Fig. 19: The final “TernVMS” typeface available from IIID.