Research Investigating Implications

of Adopting the

Unified English Braille Code

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Final Report

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The purpose of this report is to present the outcome of a project supported by the Braille Authority of North America (BANA) to conduct research on the Unified English Code (UEBC). We will begin by presenting a listing of the research questions given to us by BANA that we felt we were able to address within the limits and resources available for these studies. Following this list is a brief description of the structure of the research that was carried out. There are three distinct phases to this project which include focus groups, experimental reading studies, and text analysis. Each phase is reported separately. Finally, we will end with implications of our findings and concerns for needed further research on issues related to the adoption of UEBC.

The project addressed research questions that BANA was particularly interested in exploring. The ones partially addressed in this study include the following:

a. How will the implementation of UEBC impact readers of current codes regarding reading rates and fluency and reading proficiency?
b. What are the tangible and intangible costs of implementing UEBC including the cost of transitioning to UEBC and the cost effectiveness of the UEBC in comparison with current codes?
c. What impact will the UEBC have on the professional development needs of service providers, professional development for insturctors, and provessional development for transcribers?
d. What are the perceived advantages and limitations of implementing the UEBC including the perspectives of current adult Braille readers, children and youth who read or are currently learning Braille, parents who wish to learn Braille and service providers?

Some of the more specific questions BANA posed addressed the content analysis of texts. These questions included:

a. What is the incidence of number combinations in technical materials?
b. What are the effects of extra symbols, spaces, and pages that might occur with the UEBC as compared to current codes?
c. What is the effect of the UEBC on production issues, such as writing or computer embossing as far as time, amount of paper/ volumes needed as compared with current codes?

Questions related to literacy and learning included:

a. What are the effects on reading rate, fluency, and comprehension of the proposed code changes?
b. What will be the effect to current transcribers on learning to transcribe UEBC?
c. What will be the impact of the UEBC on the acheivement of children in learning mathematics and science materials?

It was not possible to thouroughly address all of these questions within the time frame of one year, and as with many research project, many more questions arise to be considered. We began this project by consulting with the members of the Research Committee of BANA. We examined the BANA publications BANA UEBC Sampler 1 (2001) and BANA UEBC Sampler 2 (2001), as well as the International council on English Braille web site, <http//www.iceb.org/symbols.html> for current information relate to UEBC. Earlier surveys completed by the International Council on English Braille (ICEB) provided us with opinions of Braille users in diverse countries regarding UEBC changes to the English Braille codes. These studies are included in this paper in section **5.0. References**.

To begin to address the research priorities listed above, the authors designed a research program consisting of three distinct phases. Each of these phases will be presented below. Phase I consisted of controlled focus group studies of adult Braille users, teachers of Braille and Braille transcribers. Phase II was an experimental approach of Braille reading encompassing 14 separate studies of both literary and mathematical text. Phase III focused on comparitive text analysis of current Braille codes and UEBC. We conclude this report with the implications of these findings and concerns for areas of further research on the UEBC.

1.0. Phase I Focus Group Research

Phase I was a series of five (5) focus group studies to explore effects that adopting the UEBC would have on users and producers of Braille materials. The participants in this phase of the research were professionals and end users who work with Braille on a daily or weekly basis. These groups included Braille transcribers and proofreaders, teachers of students with visual impairments in kindergarten through 12th grade settings, adult rehabilitation teachers and people who use Braille as a primary reading medium in their personal and professional work.

1.1 Procedure for Phase I Focus Group Data Collection:

To begin each session, demographic information was collected for each of the individual participant in each focus group. They were asked for their professional involvement with Braille, the number of years they have worked with Braille, and the length of training required for their Braille related activities. We were also interested in the numbers of hours per week these individuals spend either in reading for professional purposes as well as the hours spent reading Braille for personal use. For some individuals we felt it was more appropriate for them to address how many hours they spend preparing Braille for others or teaching Braille to others. Survey research on the teaching of Braille (M. Knowlton and K. Berger, 1999) indicated that knowledge of Braille codes (including letters, numerals, contractions, and punctuation), rules of the different Braille code(s), and knowledge of newly adapted code changes are absolutely necessary competencies for teachers of Braille. For the focus group subjects in our study who teach Braille, we wanted to know whether their students are at a beginning, intermediate or advanced level of Braille reading. Also, does the provided instruction concern subject matter that is at a novice or introductory level, an intermediate level which assumes some prior Braille knowledge or advanced coursework at the high school or post secondary level.

Previous surveys have explored individual evaluations of proposed code changes and individual opinions about those changes (*UBC Evaluation Reports* 1998-2000). However, questions have not been asked addressing the impact of change to the production and use of materials in UEBC, the implications for teaching this code or the relative advantages or disadvantages such a code might have for the end user. After collecting demographic information, the participants were presented with an overview of the UEBC containing 21 examples of Braille text which were presented in UEBC, English Braille American Edition (EBAE) and Nemeth code, as appropriate. The examples addressed word spacing changes, whole and part word contractions that would no longer be used in UEBC, period and decimal configurations, basic enclosure symbols, common type face indicators, numeric symbols, basic signs of operation and signs of comparison, as well as computation formats. The examples were developed with consideration to the teaching of basic reading and mathematical skills and the primary needs of most Braille students (Knowlton and Berger, op. cit.). Focus group participants were also presented with the UBEC Grade I, Numeric and Assigned Shapes Symbol List found on the web site of the International Council on English Braille at http//www.iceb.org/symbols.html. All information presented to focus group participants was available in Braille simulated Braille and enlarged print formats to be selected according to the participant's preference

The participants were to consider what impact the proposed change will have on the current professional staff trained to work with Braille codes, what level of retraining, if any, will be needed to continue their work and who might provide it. Who will develop the curriculum to teach both the school aged students and the adult Braille users, who will be competent to teach it, and what level of competency will be necessary for these teachers and how will competency in UEBC be determined. Finally, they were asked to explore what training needs exist for adult professionals who regularly use Braille in their careers. In exploring these questions we asked the participants to proceed with an assumption that the UEBC is approved.

We asked the focus group participants to address implications that adopting the UEBC might have on who might be taught Braille, the way in which they would teach the code, the impact on the students being taught, and the potential curriculum for the student. Do they expect these changes to have greater impact on the novice or the advanced student? How long do you think it would take you, the teacher, to learn the UEBC and how long do you think it would take a novice Braille reader to learn it. As part of the inquiry we also asked them to consider issues related to the conversion process. We explored their opinions as to whether a change to UEBC should be made all at once or whether multiple codes should be available at the same time during a transitional period and how long a conversion period to the UEBC might be.

The answers to these questions have a tremendous implication for how change is perceived by the professional community, the rate at which change can reasonably take place, and the success by which any changeover is successfully accomplished. We asked all participants to provide us with their professional expertise and knowledge to suggest a timetable for the restructuring the production of Braille and the teaching of the UEBC should the Braille Authority of North America approve it.

1.2 Phase I Subjects of Focus Group Studies:

A total of seventy individuals participated in the five focus groups. The group represented Braille transcribers, proofreaders, teachers, rehabilitation teachers and end users. There were fourteen transcribers, six proofreaders, sixteen end users and fifty-six teachers. Twenty- two of the individuals fit into more than one category, i.e. teacher and end user or proofreaders and end user, or teacher and transcriber.

An attempt was made to locate a sufficient number of Braille reading end users from areas of computer science, business, mathematics and science. There was not a sufficient number of these indivuduals to conduct an effective focus group.

The focus group participants were recruited from a state agency providing Braille transcription services, two large intermediate school districts serving a total of nine local urban and suburban school districts, a large residential school program, and individuals known to be professionals in their respective fields who used Braille on a daily basis.The teachers, transcribers and proofreaders were seasoned professionals with a range of professional experience ranging from seven years (a teacher) to twenty-seven years (also a teacher). The average range of experience for these groups was 15.5 to 18.7 years. The average number of years of Braille reading for the end user group was 23.2.

1.3. Phase I Results of Focus Group Studies:

Our findings reveal that the common element among the groups was that they were willing to go through the process to make a change in the Braille code if the change would make it better for the end reader. The general consensus of the focus groups was that while the proposed changes UEBC creates to the literary Braille code are minor and result in only a slight increase in passage length, the impact of the changes to the mathematics Braille code were of a much greater magnitude and would result in much longer passages. These longer passages would result in greater formatting problems, longer translations, more volumes for each book to be translated, and a greater cost for production. While the concept of writing the code was discussed only peripherally it was raised as an issue, for this code would not only be more difficult to read, it would also be more difficult to write. Specific issues raised by the transcribers are listed in Table 1.1 and those of teachers are listed in Table 1.2.

Table 1.1. Transcriber Concerns.

Number of Participants	General Concern
6	The transcription of print text to Braille, itself, is not the major issue in transcribing today. Formatting is the major issue. The new code is no more effective at addressing that issue than are our current translation programs.
13	There needs to be significant editing in the transcription of most books. The presence of pictures, tables, charts, maps, and graphs have not been addressed by UEBC.

11	There are still ambiguous rules in the code. It is not 100% clear and as a result some decisions still need to be made based on the context of the symbol.
10	There is no back translator for the program as of yet. Material written in UEBC cannot at this time be accurately converted to print.
4	The majority of Braille transcription in this country is done by volunteers. This is an aging group who may have no interest in learning the new code. As a result there will be fewer individuals to edit and format the materials as needed.
7	While electronic publishing is well underway there are currently no standards. As a result each textbook publishing company is unique in the way it sets up text, so even electronic publishing has to be handled on a book by book basis.

Table 1.2. Teacher Concerns

Number of Participants	General Concerns
40	Over the past twenty years we have seen a significant drop in the number of Braille reading students. Due to the improvement in magnification technology some of the more borderline students have been able to make the change to reading print.
31	As a result of additional disabilities, i.e. learning disabilities, cognitive disabilities, motor impairments, and other sensory impairments an increasing number of students learn to read Braille only for survival skills.
13	An increasing number of students with visual impairments are English Language Learners. They are first struggling to become fluent in the spoken language. They lag even further behind in their reading skill.
43	Given the data available from this sample only ten to thirty percent of the visually impaired student population will ever read Braille. To make the system more complex would reduce that

number even further.

17 Writing is a far more difficult task than reading. If this system is adopted student writing and computational fluency may be more impacted than their reading ability as writing is a slower skill to develop.

27 Students reading Braille are much slower at completing work than their print reading friends. This performance decrement is even more pronounced when the student is working in a mainstream classroom. To utilize a system that results in even slower performance by the readers is not reasonable.

16 Teaching and learning time for the new code will be slower, much slower in math in particular. Math is already a difficult subject for most totally blind students. If this code is adopted they will not only be learning what is a very difficult subject for most of them, they will also be learning a more difficult code at the same time.

46 Teachers estimate a minimum of five years to get a curriculum ready to teach them the code in a way sufficient to be able to teach it successfully.

32 Teachers estimate a minimum of five years for them to become fully competent and comfortable with the code.

19 Teachers foresee a transition period of 20 to 40 years where Braille materials will be maintained in both formats. From the point that teachers are prepared to teach it, with appropriate training and materials, it will take a minimum of twelve years to graduate a class of students who are capable of reading the materials. At that point there will be a group of adults from their early twenties and older who will not know the code. While changes to the literary code are less extensive and may be easily incorporated by accomplished adult readers changes to the mathematics code are far more extensive and will take much longer to learn.

21 There are thousands of volumes of Braille already available. A wholesale change to the new code would make those books obsolete. Replacement of those books would take time, transcribers, and an influx of funding, just at a time when the

production of text books would be at its highest – as EVERYTHING would need to be produced in the new code for the first time.

The Braille reading end user's mirrored many of the comments of the teachers and transcribers. (Some of them were teachers and transcribers). They were reasonably clear that as a group they could master the proposed changes to the literary code within six months. They were very clear that mastering the changes to the mathematics code would take twice that, if they bothered to learn them.

Some of the focus group participants were in school when Nemeth Code was introduced. As they were high school students at the time they chose not to learn the new code. They doubted they would learn this mathematical code either. They raised the question as to whether any student later in their school career would ever become fluent in the new mathematics or computer code unless they used it on a daily basis for an extended period of time.

They were very emphatic about one final point. They did not need to know everything on the print page. They did not need to know the font or the font size, they did not need to know the color of the type or the color of the paper. Bold face type, italics and underlining were important, but only as it added emphasis and as a result it adds specific information about the content of the material, In many instances our participants felt that less information was better. The end result being that they felt it was not a good use of space on the Braille page to have additional indicators that were superfluous.

These comments from the professional users of Braille suggest that any change of the magnitude of UEBC will have major impact far into this century on the learning and teaching of Braille. They clearly state that any changes to the code that would make Braille more difficult to read is not in the best interest of the current population of Braille readers, many of who would be greatly hampered by this more complex code. Today's population of Braille readers have significantly higher levels of learning disabilities, cognitive impairments, physical disabilities, as well as the greater presence of English Language Learners. The consensus of the group was – It doesn't matter how elegant the code is – if it ultimately reduces the access to Braille materials by reducing the number of individuals who can access it, then it has failed to meet the goal of reading and should not be adopted.

2.0 Phase II Reading Rate Research:

Phase II was an experimental study to address the impact on literary Braille reading rates created by changes to EBAE and Nemeth code by the introduction of the UEBC. Earlier research by M. Knowlton and R. Wetzel (1996) demonstrated that Braille reading rates are not constant. They vary widely depending on the purpose of the reading task. Further research (Wetzel, R. and Knowlton, M., 2000) demonstrated that Braille and print reading rates varied in a parallel manner with the Braille rates always slower than print, but impacted to a similar degree by the task. Using this as a starting point, we decided to address two reading tasks in this study. These tasks were (a) oral reading and (b) text scanning conditions.

There are severe constraints on the design of experimental studies on reading rates for UEBC. A pool of expert readers in UEBC large enough for statistical analysis does not exist. Of far greater concern are the ethical issues of using Braille reading students for this research. Braille reading students are often in the process of learning the current Braille code and have numerous additional educational needs. In the United States these needs are specifically defined in mandated individualized educational programs. There is neither the time in their schedules or the schedules of their teachers to provide participation in experimental studies. Consequently, we have used a group of consenting adult volunteers who are expert Braille or print readers as subjects for these studies. The participants were sixty adults recruited from the community and were paid twenty-five dollars each for their participation. Twenty individuals were assigned to each of one of four groups: Print Reading, Braille Mathematics Reading, and Literary Braille Reading - Contracted Form and Literary Braille Reading Non-Contracted Form. Each subject used either Print or Braille as their primary reading mode for at least 12 years and considered themselves proficient at reading. The Braille readers were chosen for the expertise in reading EBAE and Nemeth code.

To begin examining issues of reading the UEBC we decided to address reading rates for text which incorporated some of the changes from EBAE and Nemeth code using a paradigm developed by Dr. Gordon Legge and associates (G. E. Legge, C. M. Madison and J. S. Mansfield, 1999) for MNRead. MNRead is a test to assess oral reading rates and is standardized in print, non-contracted Braille (Grade 1) and contracted Braille (Grade 2). The print test is composed of a set of sentences of 60 characters in length, each of which is placed on a card in three lines of 20 characters each. An example of one of the MNRead stimuli cards is presented in Figure 2.1. The text presented is at a fourth grade reading level. The Braille versions of MNRead are transcriptions of the print form, presented in a similar format, with or without contractions and spacing, depending on whether contracted or non-contracted Braille is being considered. The line length in Braille can vary from the 20 characters per line but a three-line presentation for each sentence is preserved. The data can be analyzed in words per minute (wpm) or characters per second (cps). If a cps analysis is used for Braille the complications created by non-spaced words and use and non-use of contractions can be circumvented but still provide a reliable way to the two forms of Braille reading. When computing reading rates, in cps, Legge and associates found no significant differences between contracted and non-contracted oral Braille reading rates for the same individual. In this investigation subjects are first asked to read six passages from the MNRead stimuli developed by Legge, et al. Subjects are asked to read in either non-contracted or contracted Braille. The reading of these stimuli produces the character per second data that provides the baseline to which our other research data is compared.

Figure 2.1. An example of a MNRead card.

My father takes me
to school every day
in his big green car

2.1. Procedure for Phase II Reading Rate Data Collection

Subjects were called and scheduled to participate in the study at their convenience. Participation time ranged from 50 to 75 minutes per subject. Participants first completed the brief questionnaire to provide basic demographic information for the study. They were assigned to one of the three subject groups based on their interest and qualifications. They were then assigned to one of the two different presentation orders. Participants were then presented with one stimulus card at a time. They were instructed to read the card aloud as quickly as possible. They were told when to start. Reading time for each stimulus was recorded in seconds. The session was also taped for future review, if it was found necessary.

Data for each participant was entered into a large data matrix to allow for comparison between groups or within groups as needed. Data for each subject was coded by Reading Task, Order, and Demographic Information. Individual reading time for each stimulus card was is then entered into the database.

The total number of characters for each item was divided by the reading time for that item. This provides us with the number of characters per second read by each subject. For each stimuli it was decided to use the number of characters per second as opposed to the number of words per minute to create consistency within the analysis.

Although literary material can be analyzed on a word or character basis , a direct equivalent of a "word" in mathematics is more difficult to define. For example, the term $x+y$ can easily be interpreted as three characters but the expression $\bar{x}$ can be interpreted as one or two characters depending on the protocol for analysis. The asumption was made that mathematics is read on a character by character basis. As a result a reliable unit of measure smaller than the word is necessary to meaningfully compare reading rates across text types. In braille, however, we can use the number of cells, or characters, as the measure of length.

2.1.1 Procedures for Literary Braille Studies Reading Rate Studies. Several experimental conditions in this investigation explored the impact of specific changes to the literary code. We looked at changes in reading rate caused by inserting spaces after the words *and, for, of, the, with* and *a* when they follow each other in text. We also address the impact of dropping the whole word contractions *to, into* and *by* and inserting a space after them, as in print. The elimination of part word contractions *com, ally, dd, ation* and *ble* was also addressed. In these experimental conditions each word or contraction is examined separately. For each condition a set of six sentences was developed each of which contains the word or contraction at least twice. Each sentence is placed on a separate card. Subjects were requested to read the sentences orally as quickly as possible. They were timed on each card and errors in reading are noted as well. Table 2.1 presents a synopsis of the literary Braille reading studies.

Table 2.1 Experimental Literary Braille Conditions

Condition	**Words and letters effected**
MNRead	Contracted and non-contracted Braille
inserting spaces	*and, for, of, the, with, a*
dropping whole words	*to, into, by*
dropping part words	*com, ally, dd, ation, ble*

2.1.2 Literary Braille Studies Results. The results of the first study are presented in Table 2.2. The comparison of uncontacted Braille and contracted Braille confirm the results of earlier research by Legge, et. al (1999) the reading rate for contracted Braille was 7.90 cps. The reading rate for contracted Braille was 7.95 cps (t =.02, $p < .997$)

Table 2.2. Reading rates in characters per second on the MNRead-Braille version.

	n	cps	probability
Contracted Braille	16	7.095	
Non-contracted Braille	16	7.090	.995

The next study addressed the effect on Braille reading rates when spaces are inserted after the words *and, for of the with* and *a* when they follow each other in text. These results are reported in Table 2.3. the impact of adding spaces between these words was not statistically significant. Seventeen subjects generated an average reading rate of 7. 101 cps without spaces. When spaces were added the reading rate dropped to 6.89 cps (t = 2.832, p = .115). It is also important to point out that although the reading rate in cps is faster without spaces the text is also somewhat shorter in the actual number of character to be read in this condition.

Table 2.3 Braille reading rates with and without spacing between the words *and, for of, the, with* and *a.*

	n	cps	t-test	probability
With spaces	17	6.89		
Without spaces	17	7.10	2.832	.115

A third set of Braille reading studies addressed the effect of dropping the three whole word contractions *to, into* and *by.* For the contraction for *into* the contraction for *in* is preserved but the *to* is spelled out. These results are presented in Table 2.4. These results are not consistent. The use and non–use of *to* and *by* is clearly non-significant but for *into* there is significance at the .05 level of probability with the contracted reading rate being faster.

Table 2.4 B raille reading for text with and without the whole words *to, into* and *by*.

	n	contracted	non-contracted	F	probability
to	33	7.26	6.98	7.90	.388
into	33	6.86	6.60	4.67	.048*
by	33	6.42	6.08	7.41	.343

The results of a final set of literary Braille studies comparing the oral Braille reading rates with and without five specific part word contractions is presented in Table 2.5. The contraction addressed are *com, ally, dd, ation,* and *ble*. The results of the literary comparison of stimuli were quite clear. For all contractions the reading rates are significantly slower than the MNRead cps scores using contracted Braille. Each of these reading rate changes were highly significant at the p < .02 level. The reading rates, computed in characters per second, for the fully contracted Braille were always significantly faster than the reading rates for Braille with selected contractions dropped.

Table 2.5 Braille reading rates in characters per second when specific contractions are dropped compared to MNRead.

contraction	n	mean square	F	probability
MNRead	33	7.092		
com	16	6.394	8.022	.013*
ally	16	5.734	20.749	.000*
dd	16	6.205	14.973	.002*
ation	16	6.408	7.712	.015*
ble	16	6.335	10.523	.006*

The conclusion one is able to draw from these results is equivocal. There is a definite trend toward longer reading time in characters per second for passages with dropped contractions. But the pattern is not quite clear. This lack of clarity may be due to the small number of sentences presented in each condition, i.e. six (6), or the relative shortness of the passages (average number of characters is 47). In addition these sentences were tightly controlled. Only one contraction was eliminated for each passage. There is a significant question remaining as to the impact of eliminating multiple contractions in a passage. It is a question that needs to be answered prior to making global changes to the Braille code.

A brief study did address reading rate as a function of dropping multiple contractions within a passage. In this condition reading rates again dropped precipitously from 7.092 to 4.37 cps. However, there was a significant order effect in this segment of the study with slower readers showing a much larger drop in reading rates than the faster readers.

2.2.1 Procedures for Mathematical Braille Reading Rate Studies. In beginning to address studies in Braille mathematics reading we were unable to locate any recent research related to reading rates for mathematics in either print or Braille. Without an established standard we decided to collect data for print reading rates as well as Braille rates. Only the research of reading rates for mathematical materials in Braille is the focus of Phase II.

The format of these studies follows in much the same structure as the literary Braille conditions. Print stimuli were developed in a "60-characters-in-three-lines" per card format. In mathematical material it was not always possible to fully observe this format but each stimulus card adhered to the format as closely as possible. Sets of stimuli cards were developed for reading random one, two and three digit numbers as well as cards of mixed digits, random mixed digits interspersed with random one, two and three letter words and text with embedded numbers. Scanning text for numbers was also addressed.

The print stimuli were transcribed into EBAE/Nemeth code. Duplicate sets of the Braille stimuli were created differing only in whether the numbers were in literary positions (upper cell) or Nemeth code positions (lower cell). Three final sets of mathematical stimuli were developed. The first set consisted of short word problems that included numbers. These were transcribed into both Braille with numbers in the literary position (upper cell) and Braille with numbers in Nemeth code notation (lower cell). The second set of stimuli consisted of problems for elementary mathematical computation of addition, subtraction, division and fractions. These are provided in Nemeth code only. The third, and final set of stimuli, were longer passages that contained recipes with measurements indicated by numbers. Again, duplicate sets present numbers in literary and Nemeth code notation. These passages were created to obtain data on scanning rates for numerical information in EBAE and Nemeth numbers. The task cnditions are summerized in Table 2.6.

Table 2.6 Experimental Braille Math Conditions.

Task	**Literary Numerals**	**Nemeth Numerals**
Single digits	x	x
Double digits	x	x
Triple digits	x	x
Mixed single, double and triple digits	x	x
Mixed 1-3 cell numbers with 1-3 cell words	x	x
Numbers embedded in word problems	x	x
Mathematical computation		x
Scanning text for embedded numbers	x	x

For clarity, an example of one of the stimuli cards for the “mixed 1-3 cell numbers with 1-3 cell words” is presented in Figure 2.2.

Figure 2.2. a sample card for the1-3 cell mixed digits and numbers

2 me 428 say 8 no
got tag hat 455 27
12 17 any 67 400

In summary, the research design of the study reported here is a modified 2 x 2 mixed factorial repeated measure design. There were two levels of reading type: Literary Braille and Nemeth Braille. The stimuli are presented in two orders. Each subject received six presentations of any particular stimulus type. The stimuli being presented to any particular group varied, to cover all possible stimulus conditions while requiring the fewest number of subjects. The reading rates of these expert Braille readers provide a base for comparing UEBC and EBAE/Nemeth Braille in Phase III of the research.

2.2.2. Results of Mathematical Braille Reading Rate Studies.

An initial analysis compared reading rates for literary text (MNRead) with mathematical material using the mixed numbers and letter stimuli. When comparing these reading rates a significant drop in reading rates was found for mathematical materrial. The average literary reading rate of 7.092 cps to a reading rate of 4.49 cps resulted in a statistically significant finding at the .000 level. An additional analysis looking a computational format for elementary mathematics revealed a reading rate of only c.89 cps. This would support the assumption that Braille mathematics, unlike literary text, is a character by character reading process.

Other results in the comparison of Literary numbers versus Nemeth code numbers presented mixed results. There were significant differences in the reading rates for single digits ($p<.000$) and 1 to 3 digit numbers ($p<.01$). In both of these cases the literary numbers were read faster. However, in four other experimental conditions: double digits, triple digits, mixed number and words there was no significant difference in reading rates. These findings are reported in Table 2.7.

Table 2.7. Comparison of reatding rates for numbers in EBAE and Nemeth code.

	n	EBAE cps	Nemeth cps	T	Prob.
Single digit	20	7.61	5.47	3.88	.000*
Double digits	20	4.59	4.17	.96	.342
Triple digits	20	3.83	3.82	.03	.997
Mixed digits	20	4.18	3.12	2.72	.010*
Mixed numbers and words	20	4.48	4.58	.04	.965
Numbers in text	20	21.89	21.08	.63	.966
computation format	20	--	3.89		

A final experimental condition to address the ability to scan text for numbers required subjects to first silently read instruction for cooking recipes and the serch the text for responses to specific questions related to quantities stated in the text.

Text conditions presented numbers in either EBAE or Nemeth code positions. Ther was no significant difference in the scanning rates for the two conditions (p< .966). these results are presented in Table 2.8.

Table 2.8. Comparision of scanning reading rates for numbers in EBAE and Nemeth codes.

	n	EBAE cps	Nemeth cps	T	Prob.
Scanning text	20	22.08	21.89	.04	.966

The results obtained in the mathematical Braille studies need to be interpreted with the same degree of caution as the results of the literary studies. Subjects were asked to read a series of numbers orally. The average number of Braille symbols per card was 60 cells. The actual number of characters read per card varied as a function of number length. This was a very specific task, assessing oral reading speed as a reliable indicator or reading rate, but it is not a real world situation. The comparable reading conditions need to be addressed with more “real world” stimuli. The interesting finding is that two digit, three digit, number-word and recipe material indicated absolutely no difference is reading speed between upper and lower cell numbers. These more complicated tasks are somewhat more indicative of the real world, and suggest that the reading rate will be more influenced by the number of characters, spacing, and nature of the reading task than by the position of the numerical symbols in the Braille cell.

3.0. Phase III: Text Analysis Studies

Phase III of the research indirectly addresses the impact on reading of text in EBAE/Nemeth and UEBC. As stated above, we are unable at the present time to do subject based reading rate studies using UEBC since we are unable to obtain a sufficiently large population of expert readers of UEBC. Instead, we proposed to do a comparative text analysis of EBAE/Nemeth with UEBC text samples based on character/cell counts. It is assumed, based on the character per second reading rate studies of Phase II, that more Braille cells and more Braille pages will require longer reading times for equivalent material.

3.1.Procedures for Phase III Text Analysis Data Collection. Comparisons of nine different text samples of UEBC and EBAE were conducted. The text length for each sample was computed and the comparative length of the material in EBAE/Nemeth and UEBC was noted. Two samples each of Arithmetic, Algebra and Computer text were taken from the *BANA UEBC Sampler 2.* The first arithmetic sample is found in print on page 9 in *Sampler 2.* It consists of a set of spatial arithmetic problems which include examples of addition, subtraction and multiplication containing a total of 403 print characters. The second arithmetic sample (print form on page 183 in *Sampler 2*) consists of 8 problems in basic arithmetic displayed in linear fashion and includes addition, subtraction, multiplication, and division. It contains 404 print characters. The first algebra text selection (print form on page 57 in *Sampler 2*) consists of 30 algebra problems and requires 722 print characters. The second algebra selection (print form on page 59-60 in *Sampler 2*) includes 50 problems presented for factoring. This selection requires 1191 print characters. Two samples of a computer program were selected from the sampler. The first (page 224 in *Sampler 2*) has requires 17 lines and has 511 print characters. The second computer sample (page 231 *Sampler 2*) requires 13 lines and has 400 print characters.

Finally, samples of literary text were selected from three popular children's books. They included approximately three print pages each of text from *Charlotte's Web* by E.B.White, *On the Shores of Plum Creek* by L.I.Wilder, and *Quidditch Through the Ages* by J.K. Rowlings. These samples require 1840-2095 print characters each with a mean of 2000 print characters.

Analyses of the arithmetic, algebra and computer samples were done using *the UEBC Sampler 2* simulated Braille transcription in Nemeth code and UEBC. The selected literary samples were transcribed into EBAE and UEBC for comparison. Comparisons were made of character/cell counts, lines, and word wraps required when transcribing the print selections.

3.2.Results of Phase III Text Analysis. The text comparison of EBAE/Nemeth code with UEBC yielded the results presented in Table 3.1. These include two samples of arithmetic, two of algebra, two of computer code and three of literary text. The increase or decrease in total cell count for each of the selections was computed.

Table 3.1 Character, Line and Word Wrap counts for selected examples to compare EBAE/Nemeth/computer codes with UEBC.

	print		**EBAE/Nemeth/ computer codes**			**UEBC**			**Amount change**	
	char/ cell	line	char/ cell	line	wrap	char/ cell	line	wrap	char/ cell	%
arithmetic 1 spatial	403	17	491	43		599	43		108	+21.9
arithmetic 2 linear	404	$\frac{41}{2}$*	447	26		452	26		5	+ 1.1
algebra 1	722	19	698	33		1801	41	7	383	+54.8
algebra 2	1191	25	1239	26		1812	73	18	573	+46.2
computer 1	511	16	650	25	4	620	30	9	30	- 4.5
computer 2	400	14	587	25	8	594	25	9	7	+ 1.1
text 1	1840	44	1510	47		1574	47		64	+4.2
text 2	2095	34	1597	48		1664	48		67	+4.1
text 3	2065	41	1514	46		1620	46		106	+7.0

*The format of this section of text was 42 lines in two columns.

As can be seen from this analysis the impact of UEBC versus EBAE/Nemeth varies depending on the type of text being transcribed. Modest increases in text length of four to seven percent result when using UEBC rather than EBAE for the literary text. This variability may be a result of text complexity. The third sample from *Quidditch Through the Ages* presents the greatest difference between the two codes. This text is at a higher grade level where the eight contractions dropped in from EBAE may be more frequent than in the other two literary text selections.

A new rule change made for UEBC regarding rule spacing with signs of operation was made after the initial calculations for Phase III were computed. The new rule leaves spacing before and after signs of operation to the discretion of the transcriber. Since the use or non-use of spacing in these circumstances is optional character/cell counts were recalculated to present options with this rule change. Table 3.2 presents the data for the arithmetic and algebra section eliminating spacing in these situations. This change would not effect the computer or text selections samples.

Table 3.2 Character, Line and Word Wrap counts for selected examples with no spacing before and after signs of operation.

	print		**EBAE/Nemeth/ Computer codes**			**UEBC**			**Amount Change**	
	char/ cell	line	char/ cell	line	wrap	char/ cell	line	wrap	char/ cell	%
arithmetic 1 spatial computation	403	17	491	43		575	43		84	+17.1
arithmetic 2 linear	404	$\frac{41}{2}$*	403	26		434	26		4	+.001
algebra 1	722	19	698	33		943	39	5	245	+35.1
algebra 2	1191	25	1239	54		1590	64	7	351	+20.0

* The format of this text two columns in 42 lines.

Deleting the spaces before and after signs of operation in UEBC selections of arithmetic and algebra significantly reduces the length of the sample. In linear arithmetic the increase in text length between Nemeth and UEBC is non-significant but in spatial computation there is a 17 percent increase in UEBC transcription. In the case of algebra, the rule change reduces the text length for UEBC transcriptions if the spaces are deleted but the selections are still 20 to 35 percent longer than the same samples in Nemeth code.

A final analysis of two longer sections of text was made to compare Nemeth transcriptions with UEBC transcriptions. Chapters of algebra and calculus presented in *UEBC Sampler 2* were analyzed for text length in the two codes. The print text (pages 56-65), Nemeth text (68-120 even pages), and UEBC (69-121 odd pages) findings are presented in Tables 3.3 and 3.4. These transcriptions do not observe the code changes made after June 2001. The total number of lines in each chapter was counted in both Nemeth and UEBC. The number of Braille pages was calculated assuming a 25 line Braille page. A print page to Braille page ratio was calculated as a measure of text expansion.

The 9.2 pages of print text require 128 more lines and 5.2 more Braille pages in UEBC than in Nemeth code. This is 25 percent increase in Braille lines and, consequently a 25 per cent increase in Braille pages over a Nemeth code transcription as well as the increase of 25 per cent in the number of volumes required. Considering these finding in regard to an algebra book of 677 print pages transcribed into Nemeth code by the Communication Center of the Minnesota State Services for the Blind, we found it actually required 2480 Braille pages bound into 41 volumes. The averaged cost per Braille page was $5.40, creating a total cost of $13,392 for the Nemeth text. Assuming a 25 per cent increase in Braille pages, the UEBC transcription of the same book would require 620 more pages, equivalent to 10 more volumes, with an increased cost of $3,456. The total cost for the same book in UEBC is estimated to be about $16,740.

Table 3.3. A comparison of Nemeth and UEBC text length for a 9.2 print page sample of Algebra.

	lines	total pages	print:Braille ratio
Nemeth	512	20.48	1: 2.26
UEBC	640	25.56	1 : 2.778

A similar analysis was conducted for a sample of calculus presented in *UEBC Sampler 2* (pages 124-175). The Braille transcriptions in both Nemeth and UEBC do not include the eight diagrams that are presented in the print copy. The number of print pages for this sample was calculated as text only, without diagrams, to be more closely compared to the simulated Braille samples.

Table 3.4. A comparison of Nemeth and UEBC text length for 7.5 page sample of Calculus

	lines	total pages	print : Braille ratio
Nemeth	430	25.2	1 : 2.80
UEBC	482	27.28	1 : 3.03

For this sample of calculus the UEBC transcription is 8.25 percent longer when analyzed without the inclusion of text diagrams. A Nemeth calculus book currently in production is estimated to cost approximately $44,000. The UEBC transcription could be projected to cost an additional 8.2 per cent or $47,608, assuming the diagrams for the Nemeth and UEBC transcriptions require the same number of pages.

The implications of longer Braille text length impact reading efficiency, production time (transcription, materials, printing time, and binding), and the ultimate cost of Braille books. When looking at the increased number of characters needed to represent a particular passage in UEBC it becomes apparent that even for the accomplished Braille reader it will take much longer to read the material in some instances due to the increased number of pages and volumes. When considering the implication for a student learning a new Braille system the implications become much greater. These students are not necessarily reading at their top rates as the adult subjects in this study. As a result, their ability to complete these more lengthy passages will be even more compromised. At higher levels of mathematics (i.e. calculus and computer programming) the two codes seem to be more equivalent in length. The greatest differences occur in basic arithmetic calculation and algebra. These courses are more commonly taken by Braille reading students than calculus or computer programming. In Phase I we found that only about five per cent of Braille students will progress in mathematics beyond algebra.

4.0. Implications for Future Research

General findings: This study presents findings that identify concerns of Braille users and important issues to consider when changing to Braille codes. We will begin with a brief recap of the significant finding of each of the three phases or this project followed by our concerns as to the limitations inherent in the studies we have conducted. We will finish with our concerns for needed future research related to UEBC that needs to be done before any global changes are made that will impact all current and future users of English Braille.

Review of Phase I Studies. Five focus groups composed of 70 individuals who were teachers of Braille, Braille transcribers, professionals and end users who used Braille on a daily or weekly basis provided thoughtful comment regarding proposed adoption of the Unified English Braille Code. The general consensus was that they were willing to accept such changes to the Braille code if the change would make it easier for the end user.

The changes to the literary code were deemed minimal but the changes to the mathematical code were considered more complex. Professionals also wanted to see more research on Braille writing. They find that writing is more difficult and slower than reading. The population of Braille readers has declined over the past years and now includes many Braille readers with multiple disabilities or limited English skills. They find it difficult to reach and maintain the acceptable writing standards demonstrated by their peers in the current code(s) and will be even more compromised with UEBC.

The major issue identified in Braille production today is in formatting, not transcription. There are also areas which UEBC does not address. These include pictures, graphs, tables, maps, and charts. There are also ambiguous rules in UEBC and it will not be an automated translation process. It was felt that a conversion process to UEBC would take 20-40 years to train teachers and transcribers and educate a generation of students in a new code. During the conversion process it would be necessary to maintain Braille in both formats for the end users. Our participants were very direct in stating that in the end it did not matter how elegant the code is if it ultimately reduces access to Braille materials. By reducing Braille readers it has failed to meet the goal of reading.

Review of Phase II Studies. Phase II comprised a set of oral reading and scanning experimental tasks to address proposed differences created by UEBC in literary and mathematical material. Due to ethical constraints in the use of human subjects only consenting adults were used to gather these data. As with all research, caution must be used in the interpretation of the findings.

The first study replicated the findings of Legge and associates (1999) in the MNRead test, which is a measure of oral Braille reading. We found no significant difference in oral reading rates of contracted and non-contracted Braille when measured in <u>characters per second</u> ($p < .995$). A character per second (cps) was then used as a standard measure for the rest of the studies in Phase II. Higher scores in cps will not necessarily mean faster words per minute reading rates if the text is non-contracted. The cps reading rate will ultimately depend on the total number of characters to be read.

In the literary oral reading studies a comparison of text with and without spaces between the words *and, for, of, the, with* and *a* revealed no significant differences in cps ($p < .115$). A comparison of oral reading with the whole words to, into, and by contracted and non-contracted yielded mixed results. There was no significant difference found for *to* and *by.* However, the findings for *into* were significant ($p < .05$) with contracted Braille being read at a significantly faster rate. A comparison of the oral reading of text with *com, ally, dd, ation,* and *ble* in both contracted and non-contracted form were all highly significant ($p < .02$). There is a definite trend toward longer reading times in cps when these contractions are not used.

In oral reading of mathematical computation format, such as is used at elementary school levels, we found highly significant differences in reading rates when compared to MNRead literary material ($P < .000$) with math read at a much slower rate than words.

In the mathematical oral reading and scanning studies we found mixed results regarding the positioning of numerals in the upper cell (literary) or lower cell (Nemeth) positions. Oral reading rates were significantly faster for literary numbers than Nemeth numbers ($p < .01$) in conditions of reading single digits and randomly mixed single, double and triple digits. There were no significant differences between the oral reading rates when reading double digits, triple digits, mixed 1-3 digits with 1-3 cell words, and embedded numbers in text. A final study on scanning rates for numbers embedded in print revealed no significant difference between literary and Nemeth numbers ($p < .996$).

When looking at the impact of these findings in combination with the results from Phase III demonstrating the significantly increased length of passages as a result of the proposed code changes, there is a significant reason for concern, particularly during the transition phase where there may be a large learning curve. The small number of stimuli presented in this investigation does not allow for any prediction regarding the length of that learning curve, or the time frame in which expert readers will again be reading at their previous higher reading rates as measured in characters per second.

Review of Phase III Studies. In Phase III the analysis of text samples of EBAE/Nemeth and UEBC revealed that change in the total text length varied greatly with the type of text that was being compared. UEBC presented the largest increases in basic arithmetic computation format (21 per cent) and algebra (46 to 54 per cent). Even taking the new UEBC spacing rules into consideration, arithmetic computation still required 17 per cent more characters and algebra required 20 to 35 per cent more. Computer code samples indicated little difference between the two codes. The increase in text length can only partly be accounted for by extra line wraps. Basic literary text for material at the 4th grade level is 4 to 7 per cent longer in UEBC.

The impact of the longer text length effects reader, the transcriber, the number of volumes and the ultimate cost of the Braille book. In phase II we explored the Braille reading rate of mathematical and literary material in characters per second (cps). That is, the number of Braille cells read in one second. For most types of oral reading and scanning there were no statistical differences in cps rates. However, in UEBC it would still require more time to read equivalent material because there are more cells to read. Hence, we would posit that reading efficiency would decrease and that this decrease would be most noticeable at the lower grade levels with an increase of 4 to 7 percent in reading and increase of 17 to 21 percent in basic math calculation just to read the material.

The impact of longer text length on Braille production is assured since the cost of Braille is assessed as a set fee per Braille page. A hypothetical 10 per cent increase in the number of lines would result in 10 per cent more pages, 10 percent more Braille volumes, and 10 per cent higher cost for production. As has been noted, the proposed 10 per cent increase is not equal across all text. Some types of text (e.g. algebra) would generate a much higher increase in UEBC than others, such as computer programs.

Limitations of this study: When evaluating the results of these studies it is important to keep in mind the limitations of this experimental design. The readers were all expert adult readers, with Braille as their primary reading mode. The stimuli were written at a 4th to 6th grade reading level, a level that would not impose any additional cognitive burden for the reader. Subjects were presented with only six presentation of each stimuli type and the responses were all either oral reading or scanning tasks. The analysis of text was limited to a relatively few short segments of text with only four types of text addressed.

Further research: When looking at the results for Phase I, II, and III, collectively it is clear that much more research is necessary before we have sufficient knowledge to make wise decisions regarding changes to Braille codes. Such research studies would cover a wide range of topics related to the ways we encode, access and use written knowledge. We need to look at different kinds of written information and how Braille readers use that information.

Writing of Braille is an area of research yet to be addressed. The use and non-use of contractions and spacing may impact the efficiency of writing and the increased number of cells might inhibit the efficiency of text manipulation and mathematical calculation. There may also be limits related to memory load and the attention required for this kind of text manipulation.

To date there have been no studies that address the reading of graphic material in Braille. The fields of geometry, trigonometry, and calculus rely heavily on graphics. Maps, charts, graphs and diagrams also encode information in a manner that requires the use of lines, points, areas as well as text for labeling significant parts. A unified code needs to address this kind of information as well as pure literary text.

Perhaps some of the most significant research related to any Braille code needs to address a vast array of cognitive issues related to learning and using Braille as a reading/writing system. We need to replicate the current studies in both literary and mathematics fields using longer stimuli selections, diverse levels of text with a range of complexity including individuals with diverse intellectual abilities in the subject pool. The field would benefit from studies addressing short-term memory (working memory) limits as they apply to the reading, recall, and writing of Braille. Limits of short-term memory are acknowledged to be at a level of 7 ± 2 items (or bits) of information. Certain common mathematical notations easily exceed this limit in UEBC, which may impact not only the ability to learn and remember information accurately but also the ability to manipulate it in problem solving. It is possible that there is an ability to "chunk" information in higher order units. However, to date, there has been no research to support or discredit chunking in Braille. Finally, we need to address the learning curve as individuals of all ages learn to read and write Braille. Such studies would greatly inform us as we make decisions that impact our Braille learners and provide all of them access to diverse sorts of information.

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