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Dissociating Improvement of Attention and Intelligence during Written Language Acquisition in Adults

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Abstract

About one tenth of the world's population cannot read and write sufficiently. Cognitive abilities, such as selective attention and crystallized as well as fluid intelligence, have been defined as crucial factors for the acquisition of written language skills. However, it is unclear whether these abilities are necessary also for the alphabetization of adults. Before and after a one-year alphabetization course, we compared the attention and intelligence of 47 illiterate individuals to 41 matched literate controls who did not take part in the alphabetization course. Illiterate individuals improved in selective attention and crystallized intelligence from before to after the alphabetization course; however, they did not reach the same level of functioning as literate controls. In addition, the fluid intelligence of illiterates did not improve. More importantly, when controlling for attention improvement, we found that improvement in crystallized intelligence was associated with alphabetization above and beyond the influence of attention. Our results suggest that alphabetization is closely related to improvements in attention and crystallized intelligence. Specifically, socio-cultural, knowledge-specific learning processes improve during the acquisition of written language skills and may not depend on only the enhancement of the ability to attend to relevant stimuli. Alphabetization programs may, therefore, benefit from distinct considerations of attentional, intellectual, and literacy related skill acquisitions.

Keywords: Alphabetization Course, Illiterate Adults, Crystallized Intelligence, Fluid Intelligence, Attention, Written Language Acquisition

1. Introduction

This One challenge of modern societies is to educate their members in reading and writing, the so called alphabetization. Worldwide, there are about 796 million illiterate individuals, two thirds of whom are women [1]. Even in highly developed countries such as Germany, 7.5 million individuals cannot read or write proficiently [2]. Hence, understanding and improving the effectiveness of alphabetization programs is of great interest. Whereas there have been multiple investigations of cognitive abilities and their association with literacy, rather little is known about the cognitive processes underlying actual alphabetization. The present study investigates precisely this issue, looking at specific cognitive abilities and their contribution to alphabetization in illiterate adults.

Cognitive abilities, such as phonological awareness, attention, and intelligence, have been proposed to be associated with written language acquisition (for a discussion on phonological awareness, please refer to [3]). Baddeley's working memory model [4,5] assigns a primordial role to a "central executive" regarding the ability to attend to relevant and to inhibit irrelevant information. Attention and intelligence may be crucial for written language acquisition because they are of utmost importance during learning [6-9]. In fact, intelligence and attention relate to alphabetization as they allow effective investment of cognitive resources during educational processes [10,11].

Regarding literacy, a plethora of studies has shown that it is robustly associated with central executive functioning. For example, verbal span of preschoolers can predict future written language skills [12]. Further, working memory span in fourth to sixth graders is associated with the ability to read, specifically with faster reading speed [13]. Interestingly, the interrelation between central executive and written language skills (e.g., decoding speed) increases with increasing reading abilities: good readers show stronger associations than poor readers, indicating that a lack of exposure to written language leads to a weak automatization of relevant cognitive processes [14,15]. Consequently, for individuals with weakly developed reading and writing skills, understanding written language requires a greater investment of cognitive abilities, which results, in turn, in impaired performance.

Individuals with poor central executive abilities show also less flexible selective attention [16]. Reference [17] points out that decreased selective attention reduces alphabetization success, supporting the assumption that attention plays a decisive role in written language acquisition. Yet its interrelation with other cognitive abilities during written language acquisition in adults is rather unknown. With the present study, we investigated whether the influence of alphabetization on selective attention could be dissociated from the influence on other cognitive abilities associated with the central executive, namely, intelligence.

Intelligence is strongly associated with the allocation of cognitive resources [18] and may facilitate the acquisition and maintenance of written language skills. According to the general intelligence model of Cattel [19], there are two intelligence factors: fluid and crystallized. Fluid intelligence describes the capacity to find solutions for complex problems in new situations—a decisive factor for learning processes [8,20-22]. According to the investment theory [23], problem solving, reasoning, or classifying allow an efficient adaptation to new situations in which stable representations of new knowledge are formed [24]. Knowledge acquisition correlates positively with fluid intelligence level [6-9], especially if the learning process is highly complex and innovative [8,20,21, 25]. During alphabetization the learner is confronted with new and complex situations, implying a complex learning pattern [26]. For example, rhyme detection [27, 28] and syllable discrimination [29,30] have already been developed before entering primary school. These abilities are relevant not only for structuring written language, but they are important also for substituting prefixes and suffixes in order to change word meanings [31]. Fluid intelligence may support these processes and, consequently, it may support the acquisition of written language. Nevertheless, socio-cultural factors contributing to the manifestation of content-specific knowledge may affect alphabetization even more specifically.

Crystallized intelligence accounts for the capacity to accumulate knowledge based on socio-cultural and educational background [19,23,32]. It is influenced, though not exclusively, by fluid intelligence and environment-specific learning conditions such as, for example, parental socio-economic status [33]. Crystallized knowledge can be applied to solve content-specific problems [34, 35]. For example, while non-alphabetic, idiosyncratic symbols, such as Arabic numbers, do not represent phonetic or graphemic units, they reflect pronounceable words [36]. Illiterates are able to acquire the Arabic number system informally [37] and can even conduct various, though simple, calculations [10,38,39]. The proficiency in manipulating numbers indicates that symbol systems associated with simple written language demands can be acquired by illiterates, even without formal education. This form of learning, which is strongly dependent on crystallized intelligence, influences also the alphabetization process.

In the present study, the main question was whether the influence of alphabetization on attention and intelligence could be dissociated. We assessed selective attention as well as fluid and crystallized intelligence of illiterate adults before and after a one-year alphabetization course. We hypothesized that specifically crystallized intelligence scores would improve during the alphabetization course. Further, in order to dissociate attention and intelligence improvement during written language acquisition, we subdivided illiterates into two groups: those who improved significantly in selective attention during the alphabetization course and those who did not. We expected improvements in attention to affect improvements in intelligence if attentional abilities were the driving factors of alphabetization. Finally, we compared attention and intelligence between illiterate and literate individuals.

2. Material and Methods

2.1. Participants

Literate controls ($n = 41$) were matched to illiterate individuals ($n = 47$; **Table 1**). All illiterate individuals and three literate controls were of non-German origin who have been living in Germany for an average of 11.5 years (standard deviation, SD = 7.8 y) at the time of testing. Literate controls were carefully selected regarding education duration. The study followed guidelines in accordance with the Declaration of Helsinki (1964). All participants were paid and provided consent before inclusion.

Table 1. Demographic information for the two participant groups.

	Illiterate group	Literate group
N	47	41
Gender	29F	21F
Age	38.3 (8.8)	34.0 (11.3)
Years of education	4.4 (3.9)	11.2 (1.4)
Handedness	44R, 3L	39R, 1L, 1M
Course attendance (days)	132 (34)	-

Note: N = number of participants; F = females; years of education = number of years individuals spent in regular school (12 = university entrance certification); R = right-handed; L = left-handed; M = mixed-handed; course attendance = length of time illiterates took part in the alphabetization course; numbers in parentheses = standard deviations.

2.2. Materials

2.2.1. Procedure

To evaluate the improvement of abilities associated with alphabetization, the illiterate group was tested before being included in the course (T1) and after having been trained (one year later, T2). The alphabetization course entailed weekly sessions where participants were presented with letters, words, and short phrases from different topics relevant to their daily lives (e.g., buying groceries). In addition to visual and auditory material for each new letter, participants received feedback each week about their performance. With increasing competence level, participants were offered the possibility to self-paced e-learning.

There was only one testing session for the literate controls since they did not participate in the alphabetization course. Participants were tested in groups of ten. The order of tests was always in the order in which they are described below. Due to technical difficulties, the data from the d2 test for two illiterate individuals and the data from the CFT-20-R for one illiterate individual were excluded from analyses.

2.2.2. Stimuli

The d2 test of attention. The d2 test [40] is a language-independent test that evaluates selective attention. The test requires participants to detect and cross out targets (letter d with two dashes) as quickly and accurately as possible while ignoring distracters (e.g., letter d with one or three dashes). The test consists of 14 rows, each containing 47 signs. The time limit for each row is 20 s. We report a measure for attention calculated from the quality, quantity, and time of the d2 performance. The test takes 8 minutes.

CFT-20-R. The CFT-20-R is a language-free test assessing fluid intelligence [19] independently of culturally specific knowledge [41]. The first part of the CFT-20-R consists of four subtests, namely, sequence completion, classification, matrices, and topology. The tasks of each subtest are in multiple-choice formats and are ordered from easiest to most difficult. The number of correct responses allows for the calculation of a fluid intelligence score. The test takes 14 minutes.

CFT-ZF-R. The CFT-ZF-R is also a language-free test assessing crystallized intelligence [19] by testing numerical processing capacity [41]. It consists of 21 multiple-choice tasks in which number sequences have to be continued in a logical way. The number of correct responses allows for the calculation of a crystallized intelligence score. The test takes 12 minutes.

2.2.3. Data Analysis

PASW 18 (Predictive Analysis SoftWare) was used to perform statistical analyses. Data were, unless otherwise specified, normally distributed (Kolgomorov-Smirnov test). The significance level for all statistical tests was 0.05.

For all tests, the raw data were converted into standardized values representing percentile ranks. A percentile rank of 25%, for example, implies that the individual performed better than 25% and worse than 75% of his/her age group.

To investigate whether the illiterate group improved on the experimental measures, we used paired t-tests with time of testing (before the alphabetization or T1 vs. after the alphabetization course or T2) as a within-subjects factor for the illiterate group. Further, the test results were compared between groups (illiterate vs. literate) using independent t-tests separately for the first (T1) and the second (T2) testing sessions of the illiterate group.

To dissociate the influence of attention and intelligence on written language acquisition, we subdivided the illiterate group based on their improvement on the d2 test: high d2 improvement and low d2 improvement from T1 to T2. We investigated whether both subgroups differenttially improved on the other tests. In other words, did individuals who improved highly (weakly) on the d2 also improve highly (weakly) on the other tests? There were two approaches to test this. First, we compared test performances between times of testing (T1 vs. T2) using paired *t*-tests individually for the two subgroups. Second, we calculated an improvement measure for each test as the difference between test performance at T2 minus test performance at T1. We then used independent sample *t*-tests to compare improvements between subgroups (illiterates who showed low vs. high d2 improvement) in each test.

3. Results

3.1. Demographic Variables

The literate and illiterate groups did not differ in gender, $\chi^2_{(1)} = 0.98$, $p > 0.05$), age ($t(86) = -2.03$, $p > 0.05$, or handedness, $\chi^2_{(2)} = 1.90$, $p > 0.05$, but did differ in years of education, $t(59) = -11.12$, $p < 0.01$; see **Table 1**.

3.2. d2 Test of Attention

Participants in the illiterate group improved in d2 performance from T1 to T2, $t(44) = -5.71$, $p < 0.01$. Compared to the literate group, participants in the illiterate group performed worse at T1, $t(57.35) = -8.62$, $p < 0.01$, and at T2, $t(83) = -3.98$, $p < 0.01$; see **Table 2**.

3.3. CFT-20-R

Participants in the illiterate group did not improve in their fluid intelligence scores from T1 to T2, $t(45) = -1.79$, $p > 0.05$. Illiterate individuals showed worse performance at T1, $t(66.99) = -11.31$, $p < 0.01$, and T2, $t(85) = -9.67$, $p < 0.02$, compared to the literate group.

3.4. CFT-ZF-R

Participants in the illiterate group improved in their crystallized intelligence scores from T1 to T2, $t(46) = -2.69$, $p < 0.01$. Compared to the literate group, the illiterate group's performance was worse at T1, $t(43.99) = -9.37$, $p < 0.01$, and T2, $t(67.35) = -7.11$, $p < 0.01$.

3.5. Controlling for Attention

According to the d2 improvement of the illiterate group, we differentiated between a high-improvement subgroup (HI, mean d2 improvement = 41.9 (±18.6) percentile ranks, $n = 17$) and a low-improvement subgroup (LI, mean d2 improvement = 0.8 (±1.2) percentile ranks, $n = 15$). This enabled us to control for the influence of attention improvement regarding the improvement of intelligence during written language acquisition without relying on, e.g., correlational analyses. Regarding the CFT-20-R (fluid intelligence), neither subgroup improved from T1 to T2 (HI-group: $t(14) = 1.58$, $p > 0.05$; LI-group: $t(15) = 1.51$, $p > 0.05$). Further, the CFT-20-R improvement score (score at T2 minus score at T1) did not differ between subgroups, $t(29) = -1.45$, $p > 0.05$. Regarding the CFT-ZF-R (crystallized intelligence), the subgroup improving strongly in d2 scores showed a trend toward improvement from T1 to T2 (HI-group: $t(14) = -1.83$, $p = 0.09$; LI-group: $t(15) = -1.45$, $p > 0.05$). The subgroups did not differ in CFT-ZF-R improvement, $t(29) = -1.80$, $p > 0.05$. Together, these results suggest that selective attention improvement during the alphabetization course is mostly unrelated to the improvement in intelligence during the same period (see **Figure 1**).

Table 2. Results of the cognitive tests for the illiterate group (two assessments) and the literate group (one assessment).

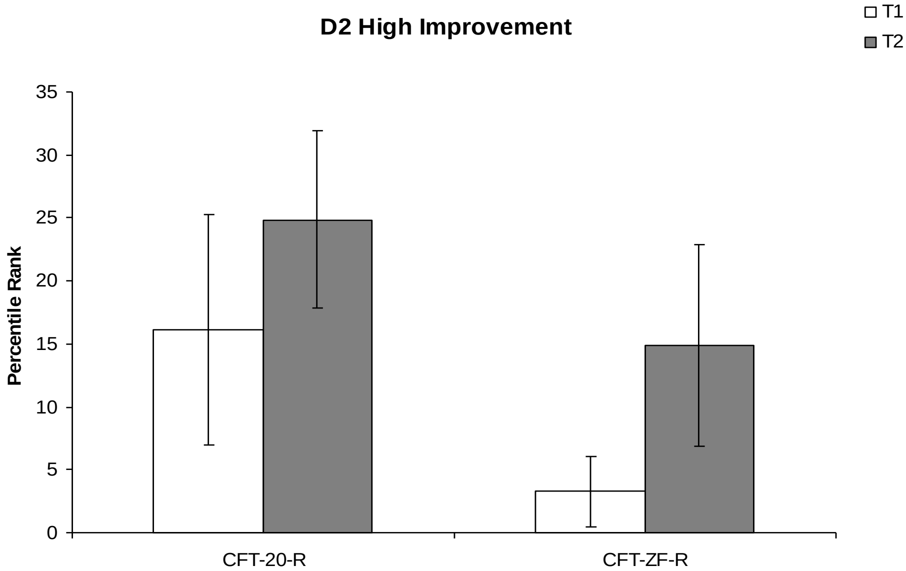
	Illiterate group		Literate group
	Before the alphabetization	After the alphabetization	
d2	**7.2 (15)**	**25.0 (30)**	49.9 (28)
CFT-20-R	7.4 (18)	11.1 (24)	63.6 (27)
CFT-ZF-R	**2.0 (7)**	**8.0 (20)**	47.4 (30)

Note: All values are given in percentile rank according to the tests' manuals. On all tasks and at all times, the illiterate group performed worse than the literate group. Numbers in bold for the illiterate group indicate improvements in percentile rank from before to after the alphabetization class.

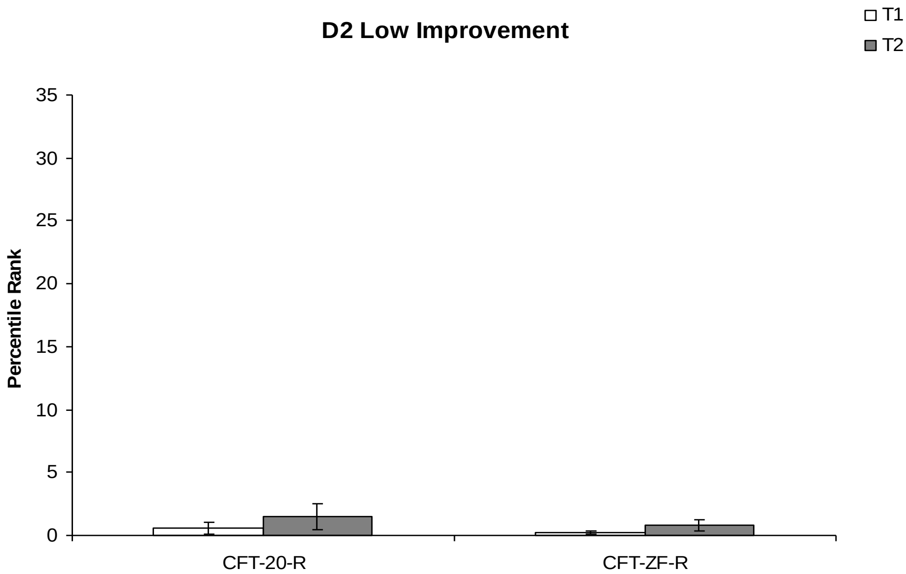
4. Discussion

The present study investigated how attention and intelligence are affected by alphabetization in illiterate adults. Whereas crystallized intelligence and selective attention improved from before to after the alphabetization course, fluid intelligence did not. When controlling for attention improvements, the improvement patterns of intelligence during the alphabetization course did not change: crystallized intelligence improved regardless of attention; fluid intelligence did not improve regardless of attention. Despite showing enhanced selective attention and crystallized intelligence at the end of the alphabetization course, illiterate individuals did not reach the performance levels of literate individuals. We conclude that improvements of selective attention during alphabetization do not necessarily influence intelligence improvements. Thus, attention and intelligence measures may make unique contributions to the acquisition of written language skills.

According to our main hypotheses, during alphabetization adult illiterates selectively improve in their cognitive abilities. Attention and crystallized intelligence improvements paralleled the administration of a one-year alphabetization course. This is in line with studies showing that better attention and intelligence scores are associated with higher alphabetization [17,31,37]. Furthermore, crystallized intelligence can be improved as a function of available knowledge and intellectual demands [42-44]. Due to developing literacy, there is an acquisition of new knowledge, which can be applied to new situations. As a consequence, previously inaccessible information can be accessed and, in turn, serves as a



(a)



(b)

Figure 1. **(a) Intelligence test performance (CFT-20-R and CFT-ZF-R) of the d2 high-improving group (HI) at T1 (before the alphabetization course) and T2 (after the alphabetization course); (b) Intelligence test performance (CFT-20-R and CFT-ZF-R) of the d2 low-improving group (LI) at T1 (before the alphabetization course) and T2 (after the alphabetization course).** ***Note*****: in the D2 high-improving group, variability of the percentile rank was more pronounced compared to the D2 low-improving group. This may have been due to the fact that the majority of individuals in the D2 low-improving group had zero improvement; in other words a floor effect.**

foundation for providing new knowledge input and new knowledge manifestation.

More importantly, our results showed that the process of "crystallizing" new knowledge appears to be possible even above and beyond the influence of attentional functions. We dissociated the improvement of crystallized intelligence and selective attention. Specifically, we controlled for attention by subdividing illiterate individuals according to their attentional improvement score. This method has, to our knowledge, not been used before. By explicitly not relying on correlational analyses, which are typically used in the literature, we demonstrate that crystallized intelligence increased regardless of whether attention improved or not. This specifies former research showing that automatization of cognitive processes increases with better written language abilities [14,15]. Specifically, exposure to written language requires illiterates to allocate more cognitive resources and, therefore, to extensively practice intellectual abilities during alphabetization programs. According to our results, this allocation of cognitive resources may be independent of attention training effects.

Fluid intelligence measures did not improve and were also not influenced by attention improvement during alphabetization. According to Cattell [19], fluid intelligence is a decisive factor when learning to solve [8,21, 22] and when actually solving complex problems [20, 25]. The results of the present study suggest that alphabetization does not reflect improvements in fluid intelligence. This may be due to the fact that in order to acquire written language skills, children rely on cognitive abilities that were acquired before entering primary school [26-29] and that may be culturally specific [45]. For example, [46,47] showed that children from the United Kingdom and from Zambia did not differ when reproducing abstract patterns with clay. However, British outperformed Zambian children when reproducing patterns with papers and pencils. By contrast, Zambian were better than British children when reproducing patterns with wires. Hence, the familiarity with material properties can influence the development of cognitive abilities [48], implying that the ability to recognize rules or regularities and to draw inferences [49] can be supported by domain-specific learning processes and knowledge [33]. Instead of fluid intelligence, culture-specific expertise, that is, crystallized intelligence, may be the decisive factor for written language acquisition success [50].

In line with former studies [51,52], our results confirm that illiterate individuals do not reach cognitive abilities as shown by literate controls. Indeed, in cognitive tests that are related to written language, illiterate individuals have demonstrated performance comparable to that of preschoolers [51]. In the present study, it can be assumed that the cognitive abilities of illiterate individuals were not trained as effectively as would have been necessary in order to reach the level of literate individuals. Before the alphabetization course, attention was below the lower norm. The decreased exposure to educationally relevant contents mediated by illiteracy may have impeded the development of cognitive functions [10,53-56]. Thus, the weak automatization of cognitive processes affects the effective interplay regarding not only written language skills, but also attention and intelligence. During adulthood, this may increase difficulties when acquiring new knowledge, specifically written language skills.

The present investigation has some limitations. The sample size was small and the duration of the alphabetization course was relatively short. Future studies should look further into, first, how cognitive abilities can be improved. Second, given the difference in fluid intelligence between the literate and illiterate group in our sample, future investigations should investigate how illiterate individuals can possibly reach the level of literate individuals longitudinally. Third, the control group was only tested once whereas the illiteracy group was tested twice. Spontaneous learning might have taken place in the illiteracy group due to repeated test exposure. However, there were more than 12 months between the two testing sessions making it unlikely to produce improvement effects. Moreover, there is no evidence for performance improvement due to multiple testing in the d2-test [40]. Fourth, as a function of illiterates catching up with literates, individual written language acquisition learning rates could be identified in order to characterize the postulated increase of automatization and interrelation between cognitive abilities. Consequently, the predictive power of cognitive abilities, their interrelations, and individual improvements could be strengthened as a prerequisite for the optimization of alphabetization programs.

5. Conclusions

This study illuminated specific aspects of the interplay between attention, intelligence, and alphabetization. Selective attention and crystallized intelligence, but not fluid intelligence, of illiterate adults improved during a one-year alphabetization course. However, illiterates did not attain the same level of cognitive functioning as shown by literate controls. Interestingly, crystallized intelligence improved above and beyond the influence of attentional improvement. These results suggest, first, that alphabetization is closely related to improvements in attention and socio-cultural (*i.e.*, knowledge-specific) learning processes. Second, these learning processes probably do not depend on *only* an increase in the ability to attend to relevant stimuli. Third, alphabetization success may be improved by taking into account attention, intelligence, and literacy related factors, separately.

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