

Giftedness, handedness, and word length effects on interhemispheric transfer and neural efficiency

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Abstract. Interhemispheric Transmission Time (IHTT) is a key indicator of cognitive processing efficiency. This study investigates IHTT differences – computed by subtracting incongruent from congruent conditions – to determine the effects of word length, handedness, and participant type. A total of 120 participants were divided into four groups: 30 right-handed gifted, 30 left-handed gifted, 30 right-handed non-gifted, and 30 left-handed non-gifted students. Giftedness was evaluated using the Behavioral Characteristics Checklist for Gifted Students, Abraham's Creative Thinking Test, and Raven's Progressive Matrices. IHTTs were measured using Arabic words of varying lengths in a factorial experimental design. Results revealed that gifted students exhibited significantly faster IHTTs, indicating enhanced interhemispheric communication and more efficient cognitive processing. A main effect of hand dominance was observed, with right-handed individuals demonstrating faster IHTTs than left-handed individuals, while word length did not significantly affect IHTTs. Moreover, a three-way interaction among word length, handedness, and participant type emerged: non-gifted students showed variations in processing words of different lengths, an effect absent in gifted students. These findings underscore the impact of giftedness on cognitive processing, particularly regarding interhemispheric transfer and word processing speed.

Keywords: college students, gifted students, interhemispheric transmission times (IHTTs); RTs; Arabic word length.

Мохамед Тарік Абдельрхім, Салах Шуб. Вплив обдарованості, домінантності руки та довжини слів на обмін інформацією між півкулями головного мозку та нейронну ефективність.

Анотація. Час міжупівкульової передачі (ЧМПП) є ключовим показником ефективності когнітивної обробки. Це дослідження вивчає відмінності ЧМПП, обчислені шляхом віднімання невідповідних умов від відповідних, щоб визначити вплив довжини слова, домінантності руки та типу учасника. Загалом 120 учасників було розділено на

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чотири групи: 30 обдарованих праворуких, 30 обдарованих шульг, 30 необдарованих праворуких та 30 не обдарованих шульг. Обдарованість оцінювалася за допомогою контрольного списку поведінкових характеристик обдарованих учнів, Тесту творчого мислення Абрахам та Шкали прогресивних матриць Равена. ЧМПП вимірювали за допомогою арабських слів різної довжини в факторіальному експериментальному дизайні. Результати показали, що обдаровані студенти демонстрували значно швидший ЧМПП, що вказує на покращену комунікацію між півкулями та більш ефективну когнітивну обробку. Було спостережено основний ефект домінантності руки, причому праворукі особи демонстрували швидший ЧМПП, ніж ліворукі, тоді як довжина слова не мала значного впливу на ЧМПП. Більше того, було виявлено тристоронню взаємодію між довжиною слів, домінантністю руки та типом учасників: необдаровані студенти демонстрували варіації в обробці слів різної довжини, що не спостерігалось у обдарованих студентів. Ці результати підкреслюють вплив обдарованості на когнітивну обробку, особливо щодо міжпівкульової передачі та швидкості обробки слів.

Ключові слова: *студенти коледжів, обдаровані студенти, час міжпівкульової передачі (ЧМПП); RT; довжина арабських слів.*

Introduction

The human brain operates as a highly interconnected network in which cognitive, sensory, and motor functions are coordinated through synchronized neural communication, enabling efficient information processing and adaptive behavior (Wu et al., 2022; Herbet & Duffau, 2020). This connectivity encompasses both structural and functional links among distributed brain regions, supporting the integration of neural activity underlying perception, cognition, and action (Bassett & Sporns, 2017; Mohamed & Bendania, 2024). A central component of this integrative architecture is communication between the two cerebral hemispheres, which allows specialized neural systems to function cohesively rather than in isolation. One key measure of interhemispheric communication efficiency is interhemispheric transmission time (IHTT), defined as the time required for information to transfer between the left and right hemispheres via the corpus callosum—the principal white-matter pathway connecting the hemispheres (Quigley et al., 2003; Meissner et al., 2017).

Understanding IHTT is essential for revealing the underlying mechanisms of brain communication and its impact on various cognitive and motor functions (Mohamed, 2021; Mohamed, 2024a). This knowledge can provide insights into how different factors, such as attention and neural specialization, influence the efficiency of information transfer within the brain. Variability in IHTT reflects differences in the speed and efficiency of neural communication and has been linked to attentional processes, neural specialization, and cognitive performance (Hoptman & Davidson, 1994).

Interhemispheric communication is closely functionally linked with hemispheric specialization, the tendency for specific cognitive functions to be preferentially processed in one hemisphere, with each side supporting distinct but complementary processing roles (Gazzaniga, 2000; Kramer, 2020). For instance, language processing, including phonological and syntactic operations, is typically left-lateralized (Mohamed, 2018; Tarik, 2018), whereas the right hemisphere is more strongly involved in spatial processing and emotional evaluation (Mohamed, 2017; Mohamed, 2024 a, b). Many complex cognitive activities—such as reading and advanced language comprehension—require the coordinated involvement of both hemispheres, making efficient interhemispheric transfer essential for successful performance (Theberge, 1997; Abdelrheem, 2021; Mohamed, 2024).

Building on this foundational work, Ocklenburg and Güntürkün (2024) propose a neurobiological framework in which functional hemispheric asymmetries are inseparable from the efficiency and flexibility of interhemispheric communication, particularly via the corpus callosum. Rather than conceptualizing hemispheric specialization as a rigid division of labor, their model emphasizes an adaptive balance between within-hemisphere processing efficiency and rapid information exchange across hemispheres. According to this framework, while specialization reduces redundancy and enhances computational efficiency, complex cognitive functions—particularly language—depend on dynamic, bidirectional interhemispheric integration. Consequently, individual variability in interhemispheric transfer efficiency is expected to manifest in measurable behavioral asymmetries during language-related tasks, linking neural organization to observable performance outcomes.

Within this framework, IHTT serves as a key behavioral index of interhemispheric communication efficiency. In the domain of language processing, rapid transfer of information between hemispheres supports the integration of phonological, lexical, and semantic components necessary for fluent comprehension and production (Hoptman & Davidson, 1994; Mohamed & Shoeb, 2025). For instance, tasks that place high demands on coordination across hemispheres, such as complex linguistic, mathematical, or problem-solving activities, are particularly sensitive to variations in IHTT, making this measure well suited for investigating individual differences in neural efficiency.

Interhemispheric transmission times have been extensively studied using reaction-time paradigms, lateralized visual field tasks, and neuroimaging techniques (Bryden & Bulman-Fleming, 1994). Research has identified three primary forms of interhemispheric transfer: (1) the transfer of information from a non-specialized hemisphere to a specialized hemisphere via neural pathways (Doron & Gazzaniga, 2008); (2) functional integration between hemispheres during the processing of different stimuli (Jin et al., 2020); and (3) dynamic

redistribution of attentional resources across hemispheres (Gazzaniga, 2000). These processes are primarily mediated by fibers within the posterior corpus callosum, which facilitates the transfer of visual information between posterior and temporal cortical regions (Abdelrheem, 2021). Prior research further suggests that enhanced interhemispheric communication may be associated with superior cognitive performance in specific populations. For instance, Desco et al. (2011) reported that mathematically gifted (MG) adolescents exhibited increased activation in the right inferior parietal lobe, anterior cingulate cortex, and frontal regions compared to their average-ability (AA) peers, indicating heightened neural engagement in areas critical for cognitive integration (Mohamed & Shoeb, 2025). Similarly, Jin et al. (2006) examined neural activity related to interhemispheric transmission in gifted and typically developing children using electroencephalography. Their study, which included 25 gifted and 25 typical children, revealed neural activity patterns favoring gifted participants, suggesting that faster IHTTs may reflect enhanced neural efficiency. Such accelerated interhemispheric transfer is thought to confer a cognitive advantage by supporting more rapid coordination between hemispheres.

Further evidence for heightened interhemispheric efficiency in gifted individuals was provided by Singh and O'Boyle (2004), who found that MG adolescents exhibited little to no hemispheric asymmetry during dichotic listening tasks, in contrast to AA individuals who showed the typical left-hemisphere dominance. Moreover, in hierarchical letter-matching tasks, MG adolescents demonstrated no hemispheric preference for processing global versus local stimuli and performed faster and more accurately during cross-hemisphere trials. Together, these findings suggest that gifted individuals engage more bilaterally distributed neural networks, enabling superior performance on tasks that require efficient interhemispheric coordination and integration (Mohamed, 2026).

While these studies highlight individual differences in the efficiency and symmetry of interhemispheric communication, research has also identified systematic directional asymmetries in interhemispheric transmission that are observed across populations. Specifically, information transfer from the right hemisphere to the left hemisphere is often faster than transfer in the opposite direction, reflecting functional lateralization of cognitive systems (Meissner et al., 2017). Such asymmetries are particularly evident in visual processing, where hemispheric dominance patterns vary depending on eye preference and task demands (Chaumillon et al., 2018).

Much of the empirical evidence for directional asymmetries in interhemispheric transfer derives from experimental paradigms designed to isolate neural transmission times, most notably the Poffenberger paradigm (1912). This paradigm estimates IHTT by presenting stimuli laterally to one

visual field and requiring a motor response from the contralateral hand (Erbil & Yagcioglu, 2016; Friedrich et al., 2017). In incongruent conditions—where stimulus presentation and response occur in opposite hemispheres—information must cross the corpus callosum, allowing researchers to infer transfer time by comparing reaction times across conditions (Thomas et al., 2018).

While methodological approaches provide tools for measuring interhemispheric communication, empirical research has increasingly focused on identifying stimulus-level factors that modulate transfer efficiency. One such factor is word length, which has been shown to impose varying demands on interhemispheric processing during visual word recognition (Tarik, 2018). A substantial body of evidence demonstrates that IHTTs increase with the number of letters in a word, suggesting a serial or partially serial mode of interhemispheric communication (Brysbaert, 1994). Behavioral, computational, and neuroimaging studies consistently report slower response times and increased bilateral cortical activation for longer words, reflecting greater interhemispheric processing demands (Hunter & Brysbaert, 1994; Iacoboni & Zaidel, 1996; Shillcock & McDonald, 2005; Wilson et al., 2009). Electrophysiological findings further indicate delayed ERP latencies for longer words during lexical decision tasks, reinforcing the link between word length and the temporal dynamics of interhemispheric transfer (Barber & Kutas, 2007; Mohamed, 2024b).

The influence of word length on interhemispheric transfer can be further understood through cognitive models of visual word recognition. The Local Combination Detector (LCD) model posits a hierarchical processing stream in which visual features are progressively combined into letters, letter clusters, and whole words within the ventral visual pathway (Perea et al., 2020; Flick, 2023). Similarly, the Sequential Encoding Regulated by Inputs to Oscillations in Letters (SERIOL) model describes word recognition as a temporally ordered process in which retinal input is transformed into letter identities and positional codes through oscillatory mechanisms (Whitney, 2001, 2008). Together, these models provide a theoretical basis for understanding why longer words—requiring more extensive integration of letter-level information—place greater demands on interhemispheric communication (Brice et al., 2023; Hendrickson et al., 2022).

Research on visual word recognition has also consistently demonstrated a right visual field (RVF) advantage, reflecting the left hemisphere's dominance for language processing (Bryden & Bulman-Fleming, 1994). In lateralized paradigms, stimuli presented to the RVF are processed directly by the left hemisphere, whereas stimuli presented to the left visual field (LVF) require interhemispheric transfer for language-related processing. Accordingly, congruent trials—where stimulus presentation and response occur within the same hemisphere—typically yield faster reaction times than incongruent trials that require callosal transfer. However, visual field asymmetries and interhemispheric transfer dynamics are not uniform across individuals and are strongly influenced

by handedness. Left-handed individuals often exhibit reduced hemispheric lateralization for language relative to right-handed individuals, which can alter both the magnitude and timing of interhemispheric transfer (Bryden & Bulman-Fleming, 1994; Woodhead et al., 2021). Empirical studies report that left-handed participants may show faster IHTTs or smaller crossed–uncrossed differences than right-handed participants, suggesting differences in neural organization and callosal efficiency (Bernard et al., 2011; Basso & Capitani, 2006). Research demonstrates that right-handers with left-handed biological relatives (familial sinistrals) exhibit behavioral patterns in language processing that differ from right-handers without such relatives, suggesting variability in hemispheric organization associated with familial handedness (Bever, Townsend & Carrithers, 2001). Therefore, analyzing IHTTs separately for right- and left-handed participants provides insight into how handedness interacts with visual field processing and interhemispheric communication during word recognition. This approach allows us to examine not only general effects of word length and handedness but also potential differences in neural efficiency between gifted and non-gifted individuals (Mohamed & Shoeb, 2025).

Beyond handedness, cognitive ability represents another important source of individual variability in interhemispheric communication. Neuroimaging and electrophysiological studies indicate that gifted individuals often exhibit more bilateral neural engagement and faster interhemispheric transfer compared to individuals of average ability (Jin et al., 2006; Desco et al., 2011). For example, mathematically gifted adolescents show increased activation in bilateral parietal and frontal regions and reduced hemispheric asymmetry during dichotic listening and hierarchical processing tasks (Singh & O’Boyle, 2004). These findings suggest that enhanced interhemispheric integration may contribute to superior cognitive performance in gifted populations.

Despite extensive research on IHTT, word length, and individual differences, relatively little is known about how these factors interact in the context of the Arabic language. Arabic script is characterized by right-to-left orientation, cursive letter forms, and complex morphological structure, which may place unique demands on visual word recognition and interhemispheric processing (Yassin et al., 2020; Malakar et al., 2022; Habash, 2022). Moreover, few studies have examined whether giftedness and handedness jointly modulate interhemispheric transmission during Arabic word processing.

Therefore, the present study investigates interhemispheric transmission times during Arabic word recognition in gifted and non-gifted Saudi students. Specifically, it examines how word length and hand dominance influence IHTTs and whether these effects differ as a function of giftedness. By analyzing transmission times for words of varying lengths across handedness groups, this study aims to advance understanding of the neural mechanisms underlying

Arabic word recognition and to clarify how individual differences in cognitive ability and lateralization shape interhemispheric communication.

The Experiment Hypotheses

This experiment hypothesizes that gifted students will exhibit shorter interhemispheric transmission times (IHTTs) during Arabic word processing compared to non-gifted students (H₁). This prediction is supported by previous research showing that gifted individuals demonstrate enhanced neural transmission efficiency relative to non-gifted peers, including faster processing of linguistic stimuli and more efficient interhemispheric communication (Tseng, et al. 2020; Jin et al., 2006). Additionally, right-handed individuals are expected to show faster transmission times than left-handed individuals (H₂).

It is further anticipated that the difference in transmission times between gifted and non-gifted students will vary based on hand dominance, with right-handed gifted individuals demonstrating the fastest processing speeds. Regarding word length, transmission times are hypothesized to increase as word length increases (from 2-letter to 8-letter words), with shorter words being processed more quickly than longer ones (H₃). The effect of word length is also expected to differ by hand dominance (H₄), with gifted students showing less pronounced increases in transmission times compared to non-gifted students (H₅).

Additionally, the magnitude of the hand dominance effect on transmission times is predicted to differ between gifted and non-gifted students (H₆). Finally, a three-way interaction is hypothesized, where the effect of word length on transmission times will depend on both giftedness and hand dominance, with gifted right-handed individuals demonstrating the least sensitivity to word length.

To test these hypotheses, the present experiment utilized a lateralized word recognition task. Arabic words of varying lengths (2, 4, 6, and 8 letters) were briefly presented to either the left or right visual field, and participants indicated the location of the word using designated response keys. This methodology allows for precise measurement of IHTTs by comparing reaction times to stimuli presented in the visual field contralateral versus ipsilateral to the responding hand. This design provides a clear framework for evaluating the proposed hypotheses and their implications for interhemispheric communication during Arabic word processing

Method

Participants

The data were collected from 120 Arabic-speaking college students, including 60 gifted students (30 left-handed) and 60 typically developing students

(30 right-handed). Participants had a mean age of 22.14 years ($SD = 0.64$) and all had normal or corrected-to-normal visual acuity. All participants were monolingual Arabic speakers. Handedness was assessed using the Edinburgh Handedness Questionnaire (Oldfield, 1971), which allowed reliable classification of participants as left- or right-handed based on self-reported hand preference across a range of everyday activities.

Participants were recruited from the college student population through campus-wide announcements, classroom invitations, and coordination with faculty members. Gifted students were identified through institutional academic excellence programs based on standardized academic criteria, whereas typically developing students were recruited from the same academic environment to ensure comparable educational and socio-cultural backgrounds. Participation was voluntary, and no participant had previously taken part in similar experiments.

Prior to participation, all individuals completed a screening procedure to verify eligibility. Participants were excluded if they reported a history of hearing or visual impairments, reading or learning difficulties, or neurological disorders that could potentially affect task performance. Eligible participants provided written informed consent before beginning the experimental session. Handedness is associated with differences in hemispheric organization and functional lateralization, reflecting underlying patterns of neurobiological development rather than a causal influence.

Ethical Approval and Consent to Participate

This study received approval from the Institutional Review Board of the Deanship of Scientific Research at King Faisal University, Saudi Arabia (Approval No. KFU-REC-2025-May-EA000796; Approval Date: 12 May 2025). All procedures were conducted in accordance with the ethical standards of the American Psychological Association (APA) for research involving human participants.

Stimuli

This study utilized 120 Arabic words selected. The word stimuli varied in length (i.e., 2, 4, 6 and 8 letters), were written in black, and presented on a white background (for the full list of word stimuli used, see Appendix 1). At the end of the experiment, participants were asked to rate the frequency of the words using a Likert scale ranging from 1 (non-frequent) to 5 (highly frequent). The average frequency was calculated, and values were statistically compared using a one-way ANOVA across the three-word length categories. The ANOVA revealed no significant differences in frequency between the word lengths, $F(3, 116) = .83$,

$p = .64$ (Mean frequency ratings: 2-letter words = 3.63; 4-letter words = 3.72; 6-letter words = 3.80 and 8-letter words = 3.80)

Procedure

The experiment took place in a light- and sound-attenuated room (ambient illumination approximately 50 lux). Participants were seated at a viewing distance of 90 cm from a 24-inch LCD monitor (1920 × 1080 resolution; 144 Hz refresh rate). A chinrest was used to maintain a stable head position and minimize movement-related artifacts. Stimulus presentation and response recording were controlled using E-Prime Professional 2.0, ensuring millisecond-level timing precision.

Each trial began with the presentation of a central fixation cross (0.5° visual angle) for 500 ms, followed by a laterally presented Arabic word (28-point Arial font) displayed for 200 ms at 4° of visual eccentricity in either the left or right visual field (LVF or RVF). Visual field presentation was randomized across trials. Participants were instructed to indicate the visual field location of the word by pressing designated keys on a standard keyboard (“6” for right, “4” for left) using their index fingers. For left-handed participants, button assignments were counterbalanced to control for potential motor-response biases.

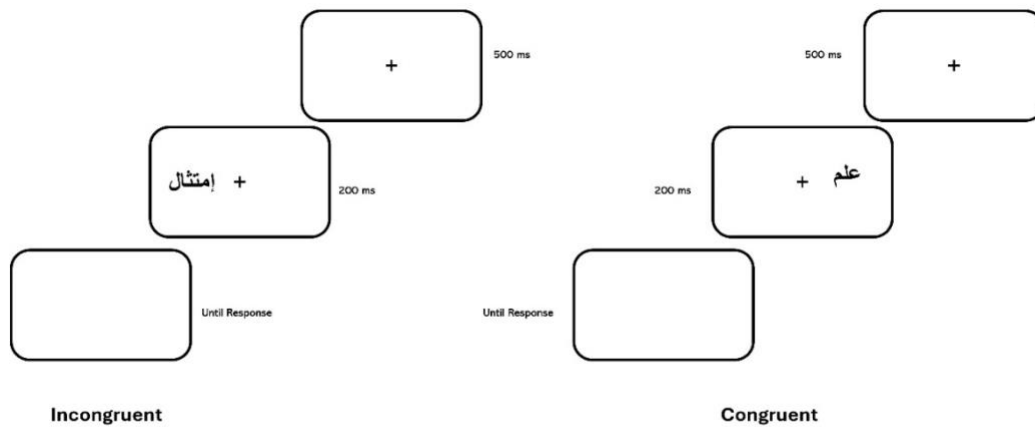
The experimental design included word length (2, 4, 6, and 8 letters) and handedness (left vs. right) as experimental factors. A total of 640 experimental trials were administered (40 trials per condition), presented in four randomized blocks of 160 trials. Short rest breaks of approximately two minutes were provided between blocks to minimize fatigue. Prior to the experimental trials, participants completed a 20-trial practice block to ensure familiarity with the task and correct understanding of instructions.

Reaction times shorter than 100 ms or longer than 1000 ms (approximately 0.3% of trials) were excluded from analysis as outliers.

Interhemispheric transmission times (IHTTs) were calculated using reaction times from congruent and incongruent conditions. In congruent trials, stimuli were presented to the visual field ipsilateral to the responding hand, requiring no interhemispheric transfer. In incongruent trials, stimuli were presented to the visual field contralateral to the responding hand, necessitating information transfer across the corpus callosum (see Figure 1). IHTT was operationalized as the difference in mean reaction times between incongruent and congruent trials. This approach yielded separate IHTT estimates for each word length, handedness group, and giftedness status, enabling precise assessment of interhemispheric transfer efficiency across experimental conditions.

Figure 1

Experimental Trials Where the Participants Should Decide If the Words Are Presented in the Right or Left Visual Field



Results

Repeated measures ANOVA were conducted to examine the effects of participant type (gifted vs. non-gifted) and handedness (right vs. left) on interhemispheric transmission times (IHTT), calculated as the difference between reaction times in congruent and incongruent conditions.

The analysis revealed a significant main effect of participant type on interhemispheric transmission time (IHTT), $F(1, 29) = 13.64$, $p < .001$, $\eta^2p = .320$. Post hoc comparisons demonstrated that gifted participants exhibited faster IHTT ($M_{diff} = -13.44$ ms), whereas typically developing participants showed comparatively slower transmission speeds (figure 2a). These findings align with Hypothesis 1. Descriptive statistics are summarized in Table 1.

Table 1

Descriptive Statistics for Gifted vs. Nongifted Students in IHTT

	95% confidence interval			
	Mean	SEM	Lower Bound	Upper Bound
Gifted	18.328	4.656	8.804	27.851
Non-gifted	31.763	1.593	28.504	35.021

Additionally, the analysis revealed a statistically significant difference in reaction times between right- and left-handed participants, $F(1, 29) = 5.876$, $p < .05$, with a moderate effect size ($\eta^2p = .168$), supporting hypothesis 2. Post-hoc comparisons

indicated that left-handed individuals exhibited slower reaction times compared to their right-handed counterparts, with a mean difference of 8.850 milliseconds (figure 2b). Descriptive statistics are summarized in Table 2.

Table 2

Descriptive Statistics for Right vs. Left-Handed in IHTT

	95 % confidence interval			
	Mean	SEM	Lower Bound	Upper Bound
Right Handed	20.620	4.697	11.013	30.227
Left Handed	29.470	1.484	26.435	32.506

In contrast, the results did not reveal a significant main effect of word length (2-letter, 4-letter, 6-letter, and 8-letter words), $F(3, 87) = 0.87$, $p = .459$, $\eta^2_p = .029$. This suggests that word length did not meaningfully impact the dependent variable. This result contradicts with H₃. It seems that the non-significant main effect indicates that variations in word length did not systematically influence performance in IHTTs, implying that word length may not be a critical factor in the cognitive processes involved (figure 2c). Descriptive statistics are summarized in Table 3.

Table 3

Descriptive Statistics for Word Length in IHTT

	95 % confidence interval			
	Mean	SEM	Lower Bound	Upper Bound
2 letter words	22.087	5.032	11.796	32.337
4 letter words	22.137	3.800	14.366	29.909
6 letter words	25.398	5.084	14.999	35.796
8 letter words	30.558	4.931	20.473	40.644

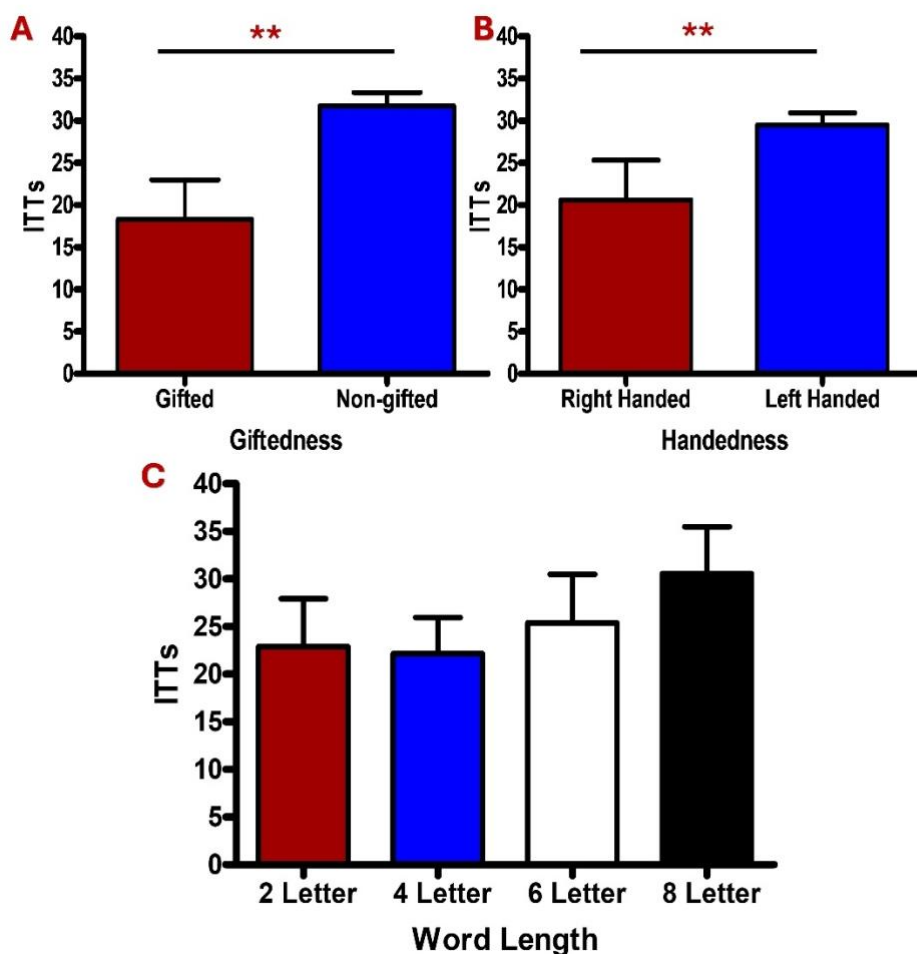
Interestingly, the small effect size ($\eta^2_p = .029$) suggests that word length contributed minimally to performance variance. It is possible that a larger sample size would be necessary to detect more subtle effects.

The two-way interaction between word length and hand dominance did not reach significance ($F(3, 87) = 1.08$, $p = .361$, $\eta^2_p = .036$). This indicates that the effect of word length on transmission times does not differ between left- and right-handed individuals. Consequently, these findings contradict Hypothesis 4, which predicted that right-handed individuals would exhibit a smaller increase in processing time with increasing word length. In other words, while H₄

expected hand dominance to moderate the impact of word length, the results show no meaningful interaction between these factors.

Figure 2

Main effects of repeated measures ANOVA: (A) Participant Type, (B) Handedness, and (C) Word Length.



Each panel illustrates the significant effects of these factors on Interhemispheric Transfer Times (IHTTs), with error bars representing the standard error of the mean (SEM). Descriptive statistics are summarized in Table 4.

These results indicate that the way processing time increases with longer words is similar for both left-handed and right-handed individuals.

Moreover, the two-way interaction between word length and participants types (gifted vs. non- gifted) students did not reach significance ($F(3, 87) = 2.306$, $p = .087$, $\eta_p^2 = .074$). The results indicate that the interaction between word length and participant type (gifted vs. non-gifted) did not reach conventional levels of statistical significance, that contradicts H₅. Although the p-value is

somewhat close to the typical cutoff of .05, it does not provide strong evidence to reject the null hypothesis of no interaction. In practical terms, this means that the effect of word length on the dependent variable (such as processing speed or interhemispheric transmission times) does not differ significantly between gifted and non-gifted students in this study. The partial eta squared ($\eta^2_p = .074$) suggests that the interaction accounts for about 7.4% of the variance, which is a modest effect size. However, this effect is not statistically reliable based on the current data. Descriptive statistics are summarized in Table 5.

Table 4
Descriptive Statistics for Word Length in IHTT

	<i>Handness</i>	<i>Mean</i>	<i>SEM</i>	<i>95 % confidence interval</i>	
				<i>Lower Bound</i>	<i>Upper Bound</i>
2 letter words	Left	21.399	4.709	11.768	31.03
	Right	22.876	5.966	10.673	35.078
4 letter words	Left	23.800	6.014	11.500	36.100
	Right	20.373	8.640	2.703	38.044
6 letter words	Left	34.700	5.749	22.943	46.457
	Right	26.095	6.395	13.016	29.174
8 letter words	Left	37.981	5.061	27.630	48.32
	Right	23.136	7.854	17.073	39.199

Table 5
Descriptive Statistics for Interactions of Participant Types by Word Length

	<i>Type</i>	<i>Mean</i>	<i>SEM</i>	<i>95 % confidence interval</i>	
				<i>Lower Bound</i>	<i>Upper Bound</i>
2 letter words	Non-gifted	23.530	3.937	15.478	31.582
	Gifted	20.745	7.164	6.093	35.397
4 letter words	Non-gifted	32.265	3.695	24.709	39.821
	Gifted	28.852	7.824	12.851	44.853
6 letter words	Non-gifted	32.815	4.958	22.674	42.956
	Gifted	31.359	8.317	5.652	28.369
8 letter words	Non-gifted	38.440	5.005	28.204	48.676
	Gifted	22.355	6.390	6.713	25.423

Furthermore, the analysis revealed a significant two-way interaction between participant type (gifted vs. non-gifted) and handedness (right vs. left) for interhemispheric transmission times, $F(1, 29) = 49.779$, $p < .001$, $\eta^2_p = .632$. This robust interaction indicates that the effect of participant type on interhemispheric transmission times depends on whether individuals are right- or left-handed. In practical terms, this means that the differences in interhemispheric transmission speeds between gifted and non-gifted students vary as a function of handedness, which supports H6. The large effect size ($\eta^2_p = .632$) suggests that approximately 63% of the variance in transmission times can be attributed to the combined influence of participant type and handedness. Descriptive statistics are summarized in Table 6.

Table 6

Descriptive Statistics for Interactions of Participant Types and Handedness in IHTT

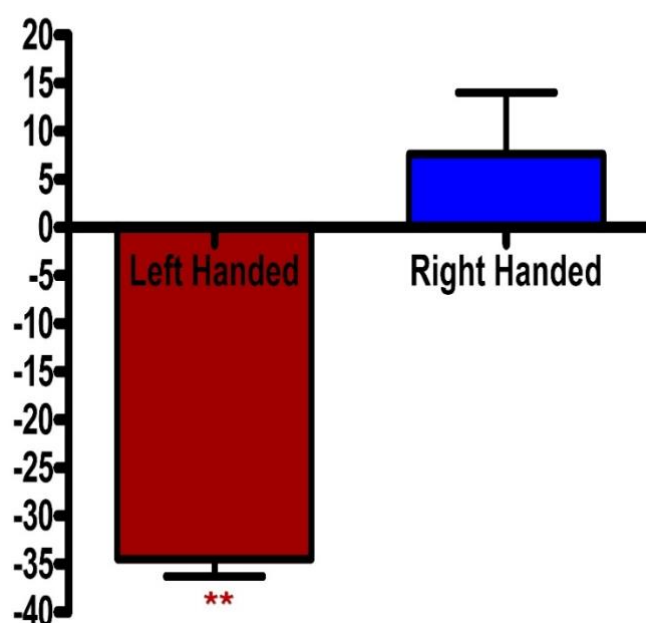
	<i>Handness</i>	<i>Mean</i>	<i>SEM</i>	<i>95 % confidence interval</i>	
				<i>Lower Bound</i>	<i>Upper Bound</i>
Non-Gifted	Left	46.709	1.731	43.168	50.250
	Right	16.816	2.359	11.990	21.642
Gifted	Left	12.231	1.729	8.695	15.767
	Right	24.424	7.689	8.699	40.149

Pairwise comparisons revealed significant differences between gifted and non-gifted students within the left-handed group. Specifically, left-handed gifted students demonstrated significantly shorter interhemispheric transmission times compared to left-handed non-gifted students (mean difference = -34.478, $p < .001$). This pairwise comparison indicates that within the left-handed group, gifted students have significantly faster interhemispheric transmission times than non-gifted students (mean difference = -34.478, $p < .001$). This effect suggests that left-handed gifted individuals may have more efficient neural communication between the hemispheres (see Fig. 3).

Finally, a significant three-way interaction among participant type, word length, and handedness was observed, $F(3, 87) = 3.516$, $p = .02$, $\eta^2_p = .108$, supporting Hypothesis 7. This finding indicates that the effect of word length on interhemispheric transmission times is contingent upon both giftedness and hand dominance.

Figure 3

Differences in Interhemispheric Transfer Times (IHTTs) Between Gifted and Non-Gifted Students, Categorized by Left- and Right-Hand Use



Note. Error Bars Represent the Standard Error of the Mean (SEM)

Pairwise comparisons revealed that among non-gifted students, significant differences emerged across all word lengths. Specifically, for 2-, 4-, 6-, and 8-letter words, the mean differences were -16.215, -35.384, -34.333, and -33.641 respectively, with left-handed non-gifted students exhibiting consistently faster transmission times than their right-handed counterparts (Figure 4). In contrast, within the gifted group, a significant difference was detected only for 4-letter words, where left-handed gifted students processed these words faster than right-handed gifted students ($M_{diff} = -38.337$). These results suggest that hand dominance modulates interhemispheric processing differently depending on the cognitive profile. In non-gifted individuals, hand dominance appears to affect processing consistently across various word lengths, whereas in gifted individuals, the effect is more selective, emerging significantly only for 4-letter words.

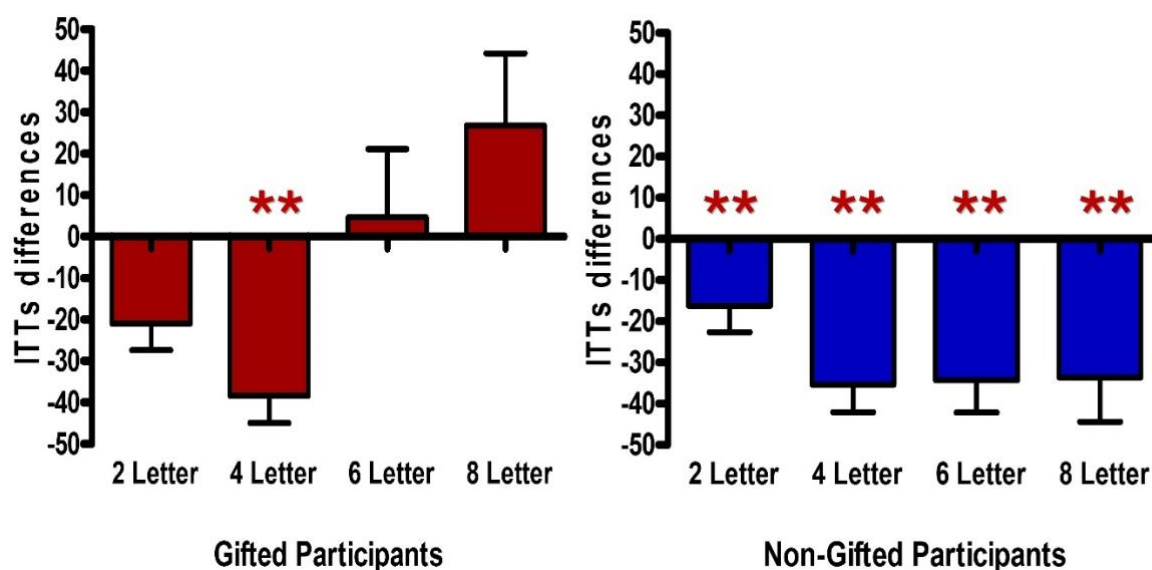
Discussion

The present study examined the effects of word length, handedness, and participant type (gifted vs. non-gifted) on interhemispheric transmission times (IHTTs). IHTTs were computed by analyzing responses to word stimuli presented in different visual fields and the activation of the corresponding

cerebral hemispheres. A total of 120 participants were included in the study, divided into four groups: 30 gifted right-handers, 30 gifted left-handers, 30 non-gifted right-handers, and 30 non-gifted left-handers.

Figure 4

Differences in Interhemispheric Transfer Times (IHTTs) Between Gifted and Non-Gifted Students, Categorized by Handedness (Right- and Left-Hand Use) Across Different Word Lengths



Note. Error Bars Represent the Standard Error of the Mean (SEM)

The results of the first hypothesis demonstrated a clear effect of giftedness: Gifted participants exhibited faster interhemispheric transfer times (IHTTs; mean difference = -13.44 ms) compared to non-gifted participants (see Figure 2a). This finding suggests that gifted individuals may possess stronger or more efficient interhemispheric connections, enabling quicker language integration. Conversely, the slower IHTTs in non-gifted individuals imply less efficient neural routing during language tasks. These outcomes align with Kranzler et al. (1994), who reported strong links between intellectual giftedness, processing speed, and task complexity. The result suggests that rapid cross-hemispheric communication is a key neural mechanism behind the enhanced language integration seen in gifted individuals, consistent with the dual-hemisphere model of language processing (Gazzaniga, 1998, 2000). In summary, the accelerated IHTTs in gifted participants likely reflect optimized neural pathways that support rapid cognitive processing, while the prolonged IHTTs in non-gifted individuals indicate less efficient interhemispheric communication. Although these behavioral findings indicate differences in neural efficiency,

confirming the underlying neurophysiological mechanisms will require neuroimaging methods such as functional magnetic resonance imaging (fMRI), transcranial magnetic stimulation (TMS), or electroencephalography (EEG). Nonetheless, the observed patterns are consistent with prior literature documenting superior information-processing efficiency in gifted populations, especially in tasks demanding rapid coordination across distributed neural networks.

The results of the second hypothesis showed the main effect of handedness, in that left-handed individuals exhibited slower reaction times compared to their right-handed counterparts, with a mean difference of 8.850 milliseconds (Figure 2b). The observed main effect of handedness aligns with established neurocognitive models of hemispheric specialization and interhemispheric communication. For instance, right-handed individuals show strong left-hemisphere dominance for language and motor tasks (Corballis, 2014), which may reduce the need for cross-hemispheric communication and speed up processing. In contrast, left-handed individuals often use both hemispheres more equally (Ocklenburg & Güntürkün, 2024), requiring extra time for signals to cross between them. This extra time likely accounts for their slower reaction times, especially in tasks that need fast integration of information (Banich, 1998). These findings support the dual-hemisphere model noted earlier. Gifted individuals showed faster IHTTs, likely due to more efficient interhemispheric connectivity, while left-handers had slower reaction times, possibly from compensatory bilateral processing that favors redundancy over speed. This contrast highlights the link between hemispheric specialization and cognitive performance.

The results also show that word length (2- to 8-letter words: $F(3, 87) = .87$, $p = .459$, $\eta^2_p = .029$) did not affect interhemispheric transfer times (IHTTs). This finding contradicts Hypothesis 3, which expected longer words to slow processing. However, it agrees with prior research indicating that tasks based on automatized processes—such as lexical access and interhemispheric transfer—are less sensitive to word length than tasks that require letter-by-letter decoding (e.g., Whitney, 2001, 2008; Perea et al., 2020). In the study task, the focus was on rapid cross-hemispheric integration rather than on sequential decoding, so participants likely processed words as whole units. With practice and expertise, reliance on basic perceptual features like word length is reduced (Marslen-Wilson & Warren, 1994), allowing for quick access to semantic or phonological information. In short, word length did not modulate IHTTs, suggesting that interhemispheric transfer favors whole-word representations over letter-by-letter processing. This result is in line with evidence that neural efficiency in automatized tasks minimizes sensitivity to perceptual variables such as word length (Mohamed, 2024).

Additionally, the two-way interaction between word length and hand dominance did not reach significance ($F(3, 87) = 1.08$, $p = .361$, $\eta^2_p = .036$). The non-significant interaction indicates that word length affects processing similarly in both left- and right-handed individuals. In other words, hand dominance does not change the influence of word length on interhemispheric transfer times. This finding is consistent with prior research suggesting that while handedness can shape overall hemispheric organization and functional lateralization (Corballis, 2014), it does not substantially alter the processing of lexical features such as word length (Banich, 1998). One plausible explanation is that the cognitive and neural mechanisms responsible for managing varying word lengths operate similarly across individuals, regardless of hand dominance. These results imply that the processes underlying the serial or parallel integration of letters within words may be robust to differences in hemispheric lateralization, supporting the notion that word-length effects are largely governed by universal visual and linguistic processing constraints rather than individual differences in handedness.

Moreover, the non-significant interaction between word length and participant type (gifted vs. non-gifted) suggests that word length did not differently impact IHTTs for gifted and non-gifted individuals. Both groups experienced similar effects of word length, which contrasts with expectations that gifted individuals may show enhanced efficiency in processing longer words. This result is consistent with research indicating that factors like cognitive ability may not substantially modify the influence of word length in tasks based on automatized processing (Perea et al., 2020; Mohamed, 2024). The lack of significance here may point to the task's nature, where high levels of task familiarity or automatization override differences between gifted and non-gifted participants.

In contrast, results showed an interaction between participants type and handedness ($F(1, 29) = 49.779$, $p < .001$, $\eta^2_p = .632$). This interaction indicates that the impact of giftedness on interhemispheric transfer times (IHTTs) varies by hand. This means that the difference in IHTTs between gifted and non-gifted individuals is not consistent for right- and left-handed individuals. Research shows that handedness is linked to structural differences in the corpus callosum, which plays a key role in interhemispheric communication (Witelson, 1989). Additionally, studies on neural efficiency suggest that gifted individuals often have enhanced brain connectivity, which may lead to faster processing speeds (Jung & Haier, 2007). Thus, the current findings imply that the neural advantages associated with giftedness are modulated by handedness, possibly due to these underlying anatomical differences.

Finally, three-way interactions between word length, participants type and handedness $F(3, 87) = 3.516$, $p = .02$, $\eta^2_p = .108$). This finding suggested that the effect of word length on IHTTs depends on both whether participants are gifted and whether they are right- or left-handed. For example, gifted individuals—who often show enhanced neural efficiency (Jung & Haier, 2007)—might process longer words faster than non-gifted ones, but this advantage can vary with hand dominance. Right-handers typically have a more lateralized brain organization (Witelson, 1989), which might lead to different processing patterns compared to left-handers. Overall, the results suggest that both cognitive ability and brain structure interact to influence how word length affects interhemispheric communication. Interestingly, pair-wise comparison show that among non-gifted students, left-handed participants showed consistently faster interhemispheric transfer times than right-handed participants for all word lengths tested (2-, 4-, 6-, and 8-letter words). This suggests that, in non-gifted individuals, hand dominance robustly influences processing speed regardless of the word's length. In contrast, among gifted students, a significant handedness effect appeared only for 4-letter words, indicating that for this group, the influence of hand dominance on processing is more selective. These differences may come from underlying neural efficiency. Gifted individuals often display enhanced brain connectivity (Jung & Haier, 2007), which might minimize the impact of hand dominance across most conditions. However, at an optimal level of task difficulty—as may be the case with 4-letter words—even the enhanced processing in gifted individuals reveals handedness differences. On the other hand, non-gifted individuals may rely more on the typical interhemispheric communication patterns. Research has shown that left-handed participants often have more bilateral language representation (Ocklenburg & Güntürkün, 2024; Witelson, 1989), which can lead to faster interhemispheric transfer compared to right-handed. Thus, the consistent advantage of left-handed individuals among non-gifted students likely reflects these established neural differences.

Limitations of the Study

Several limitations of the present study should be acknowledged. First, although handedness was systematically assessed using the Edinburgh Handedness Questionnaire, information regarding the handedness of participants' biological relatives was not collected. Previous research suggests that right-handed individuals with left-handed biological relatives may exhibit patterns of hemispheric organization and interhemispheric communication that differ from those of right-handers with exclusively right-handed relatives (Bever et al., 2001).

Consequently, the absence of familial handedness data may have attenuated potential handedness-related differences in interhemispheric transfer times (IHTTs). Future studies could strengthen the examination of handedness effects by explicitly controlling for familial handedness or by restricting samples to right-handers with exclusively right-handed biological relatives.

Second, the study relied on behavioral reaction-time measures to estimate IHTTs. While lateralized visual field paradigms provide a well-established and sensitive indirect index of interhemispheric transfer efficiency, they do not allow direct observation of neural transmission processes. Combining behavioral measures with neurophysiological or neuroimaging techniques (e.g., EEG or diffusion-weighted imaging) would allow for more direct assessment of the neural mechanisms underlying IHTTs.

Third, the sample consisted of young adult, monolingual Arabic-speaking college students, which may limit the generalizability of the findings to other age groups, bilingual populations, or speakers of languages with different orthographic characteristics. Replication across broader demographic and linguistic samples would be valuable to determine the robustness and cross-linguistic applicability of the observed effects.

Finally, although word length was manipulated systematically, other lexical variables such as morphological complexity, neighborhood density, and orthographic familiarity were not independently controlled. Future research could incorporate these factors to further disentangle their potential contributions to interhemispheric transfer during word processing.

Conclusions

The findings demonstrate that gifted individuals exhibit faster interhemispheric transfer times (IHTTs) compared to typically developing peers, reflecting enhanced neural efficiency likely supported by optimized interhemispheric connectivity. Notably, handedness was found to differentially modulate this efficiency: among non-gifted individuals, left-handed students consistently showed faster IHTTs than right-handed peers, whereas within the gifted cohort, this handedness advantage emerged only during the processing of four-letter words. This pattern suggests that giftedness may partially attenuate or reorganize typical hemispheric asymmetries, particularly under increased linguistic processing demands. Furthermore, the absence of word-length effects across groups indicates that linguistic information is processed holistically rather than sequentially, on a letter-by-letter basis.

From a broader perspective, these results offer novel insights into the interaction between cognitive ability and hemispheric organization, highlighting

the dynamic neural mechanisms that underlie giftedness. Methodologically, the study demonstrates the value of jointly considering giftedness and handedness when investigating interhemispheric communication. In terms of applicability, these findings can inform educational strategies and cognitive assessment practices by emphasizing the importance of individualized approaches that account for both cognitive ability and neural organization. While detailed applications in brain connectivity research may require further specialized investigation, the current results provide a foundation for understanding how gifted individuals may achieve more efficient interhemispheric integration during complex linguistic tasks

Data Availability Statement

Supporting data can be made accessible on the following link:
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CRediT Author Statement

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Disclosure Statement

The authors reported no potential conflicts of interest.

Generative AI Statement

This manuscript benefited from the use of Paperpal, an AI-assisted language-enhancement tool, which was employed exclusively to improve grammar, clarity, and overall readability. The tool did not generate scientific content, interpret findings, or contribute to the conceptualization, analysis, or

conclusions of the study. All substantive intellectual contributions, including the development of ideas, data interpretation, and writing of the core scientific content, were undertaken solely by the authors. The authors take full responsibility for the accuracy, integrity, and originality of the manuscript.

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Appendix

List of Arabic Words by Letter Length Used in the Experiment

Two-Letter Words	Four-Letter Words	Six-Letter Words	Eight-Letter Words
دم	أبدى	رقود	الأبجدية
فم	أزلى	دنائير	الاراميه
غم	أمدى	أوروبا	المفردات
سم	جأظ	مفردات	الأغلبه
ذو	نزیه	مباركة	المكتوبه
صه	نقاط	مرسلين	الكتابات
قط	سياق	أجمعين	المهذبون
وى	سجود	جاهليه	الخيزران
رب	أدعج	مكتوبه	المساويك
سر	وريد	مكونة	المؤمنين
حب	نادم	إختراع	المفلحون
حق	الوم	استغلظ	التقارير
جل	محال	قيلولة	الاباطيل
خل	بليغ	أعرابى	السراويل
فل	فصيح	أزاهيق	العالمية
شد	بديع	مقتدرا	الطوابير
ضل	أبجر	مجتربا	المفاتيح
ذل	أدهم	فتوحات	الجامعات
رق	إمعه	إستغنى	إهتمامات
نم	جميل	مهجوراً	الأعرابى