

Objective ages of acquisition for 3300+ simplified Chinese characters

Zhenguang G. Cai (The Chinese University of Hong Kong), Shuting Huang (The Chinese University of Hong Kong), Zebo Xu (The Chinese University of Hong Kong), Nan Zhao (Hong Kong Baptist University)

Age of acquisition (AoA) of a word refers to the age in which people first learn the word. Words that are acquired earlier in life, compare to late-acquired words, show processing advantages for participant in word recognition (e.g., Bylund, Abrahamsson, Hyltenstam, & Norrman, 2019) and spoken/handwritten word production (e.g., Chalard, Bonin, Méot, Boyer, & Fayol, 2003; Yum & Law, 2019). Besides, neuroimaging studies also shown that early-acquired words elicit greater activation in semantically related brain areas than late-acquired words (e.g., Fiebach, Friederici, Müller, von Cramon, & Hernandez, 2003). To facilitate research on AoA effects in Chinese, an AoA norms are required.

Following Liu, Shu and Li (2007) and Shu, Chen, Anderson, Wu and Xuan (2003), we constructed two AoA norms, one norm based on 18 textbooks of Chinese (corresponding to 18 terms from Grade 1 to 9) published by the People's Education Press in response to the 2001 national curriculum, and the other based on the 18 textbooks of Chinese by the same publisher in light of the 2011 national curriculum. One term is equated to 0.5 years. As children start Grade 1 at 6 years old, a character learned in the Term 1 then has an AoA of 6.5 years. There are AoAs for 3358 characters in the 2001 norm and 3395 characters in the 2011 norm (with 3013 characters available in both norms).

Descriptive results show that the current norms have significantly larger coverage of characters than previous norms developed by Shu et al. (2003) and Liu et al. (2007). We then compare these norms in terms of predicting behavioural indices in four large-scale psycholinguistic databases of simplified Chinese character processing: Sze, Rickard Liow, & Yap (2014; a character decision database), Tsang et al. (2018; a character decision database), Liu et al. (2007; a character naming database), and Wang, Huang, Zhou, & Cai (2020; a character handwriting database). As can be seen in Table 1, the current norms outperformed previous norms in explaining the behavioural data (e.g., the new norms had the two largest adjusted R^2 s in 6 out of the 8 comparisons). To further quantify such explanatory power differences, we also used the Bayes factor to assess how good a model is compare to another basing on the common characters. As is shown in Table 2, models using the 2001 AoA norm outperformed models using the Shu or Liu norm in 12 out of the 16 comparisons. Models using the 2011 norm outperformed their alternative models in 15 out of 16 comparisons (see Table 3). We also conducted a comparison between the two current norms, results shown that models with the 2011 norm outperformed models with the 2001 norm in 5 of the 8 comparisons and was outperformed in 1 comparison, with evidence being not clear in 2 other comparisons (see Table 4).

The developed objective AoAs are available at Open Science Framework (<https://osf.io/j587y/>) and can be used for subsequent research on Chinese character recognition or production.

Table 1: Regression results using different AoA norms on the four databases. All p -values for the t -tests are $< .001$; the largest adjusted R^2 is in **bold** and the second largest in *italic bold*.

	Accuracy			Reaction time		
	β	t	R^2_{adj}	β	t	R^2_{adj}
<i>Sze et al. (2014)</i>						
N2001	-0.011	-14.14	0.086	0.088	28.28	0.273
N2011	-0.011	-15.89	0.103	0.080	29.14	0.279
Shu	-0.006	-7.26	0.028	0.069	18.30	0.159
Liu	-0.006	-11.23	0.073	0.58	21.37	0.224
<i>Tsang et al. (2018)</i>						
N2001	-2.200	-13.31	0.219	0.103	18.06	0.341
N2011	-2.050	-13.49	0.221	0.103	18.23	0.341
Shu	-1.649	-6.82	0.085	0.082	9.80	0.163
Liu	-1.538	-10.36	0.176	0.074	14.94	0.309
<i>Liu et al. (2007)</i>						
N2001				16.549	25.93	0.244
N2011				15.651	26.48	0.246
Shu				15.510	15.68	0.121
Liu				12.670	30.44	0.279
<i>Wang et al. (2020), accuracy and latency</i>						
N2001	-0.049	-21.43	0.237	0.190	25.72	0.309
N2011	-0.049	-21.41	0.234	0.190	25.12	0.296
Shu	-0.029	-10.66	0.082	0.146	16.36	0.175
Liu	-0.036	-16.81	0.187	0.128	18.59	0.219
<i>Wang et al. (2020), duration</i>						
N2001	0.138	12.70	0.098			
N2011	0.127	11.71	0.083			
Shu	0.148	10.96	0.087			
Liu	0.100	10.08	0.076			

Table 2: Comparison between the 2001 norm and previous norms in explanatory power (with character log frequency and number of meanings as co-variates).

Norm	Accuracy					Reaction time					
	AoA	Frequency	Meaning	R^2_{adj}	BF	AoA	Frequency	Meaning	R^2_{adj}	BF	
<i>Sze et al. (2014): N2001 vs. Shu</i>											
N2001	-0.005***	0.008***	-0.000	0.050	177	0.054***	-0.101***	-0.007	0.319	>1000	
Shu	-0.003*	0.009***	-0.000	0.044		0.035***	-0.110***	-0.007	0.299		
<i>Sze et al. (2014): N2001 vs. Liu</i>											
Cai	-0.005***	0.007***	-0.001	0.042	0.15	0.058***	-0.101***	-0.005	0.320	>1000	
Liu	-0.005***	0.007***	-0.002	0.044		0.050***	-0.109***	-0.002	0.311		
<i>Tsang et al. (2018): N2001 vs. Shu</i>											
N2001	-1.132**	2.374***	0.254	0.170	15	0.081***	-0.105***	-0.016	0.340	>1000	
Shu	-0.756**	2.517***	0.285	0.161		0.040**	-0.122***	-0.019	0.293		
<i>Tsang et al. (2018): N2001 vs. Liu</i>											
N2001	-1.048**	3.096***	-0.048	0.222	2.0	0.065***	-0.146***	-0.010	0.398	5.2	
Liu	-0.935*	3.189***	-0.102	0.219		0.060***	-0.151***	-0.007	0.393		
<i>Liu et al. (2007): N2001 vs. Shu</i>											
N2001						12.22***	-13.75***	-0.828	0.227	>1000	
Shu						8.144***	-15.45***	-0.791	0.197		
<i>Liu et al. (2007): N2001 vs. Liu</i>											
N2001						16.56***	-17.07***	-1.197	0.302	>1000	
Liu						14.24***	-19.28***	-0.630	0.289		
<i>Wang et al. (2020): N2001 vs. Shu</i>						<i>Wang et al. (2020) latency: N2001 vs. Shu</i>					
N2001	-0.022***	0.041***	0.005	0.177	>1000	0.140***	-0.177***	0.007	0.319	>1000	
Shu	-0.015***	0.044***	0.005	0.166		0.111***	-0.190***	0.007	0.292		
						<i>Wang et al. (2020) duration: N2001 vs. Shu</i>					
N2001						0.042*	-0.270***	-0.049*	0.206	0.002	
Shu						0.080***	-0.255***	-0.047*	0.214		
<i>Wang et al. (2020): N2001 vs. Liu</i>						<i>Wang et al. (2020) latency: N2001 vs. Liu</i>					
N2001	-0.035***	0.047***	0.002	0.226	0.89	0.143***	-0.195***	0.008	0.340	>1000	
Liu	-0.034***	0.049***	0.004	0.226		0.131***	-0.208***	0.013	0.331		
						<i>Wang et al. (2020) duration: N2001 vs. Liu</i>					

N2001							0.065**	-0.249***	-0.033	0.189	6.7
Liu							0.050*	-0.258***	-0.031	0.187	

Table 3: Comparison between the 2011 norm and previous norms in explanatory power (with character log frequency and number of meanings as co-variates).

Norm	Accuracy					Reaction time					
	AoA	Frequency	Meaning	R^2_{adj}	BF	AoA	Frequency	Meaning	R^2_{adj}	BF	
<i>Sze et al. (2014): N2011 vs. Shu</i>											
N2011	-0.007***	0.008***	-0.001	0.066	>1000	0.051***	-0.105***	-0.005	0.324	>1000	
Shu	-0.003	0.010***	-0.001	0.054		0.035***	-0.113***	-0.006	0.308		
<i>Sze et al. (2014): N2011 vs. Liu</i>											
N2001	-0.008***	0.007***	-0.001	0.066	44	0.062***	-0.104***	-0.005	0.348	>1000	
Shu	-0.007***	0.008***	-0.002	0.062		0.049***	-0.114***	-0.002	0.334		
<i>Tsang et al. (2018): N2011 vs. Shu</i>											
N2011	-1.158***	2.305***	0.336	0.204	49	0.078***	-0.108***	-0.023	0.349	>1000	
Shu	-0.695*	2.557***	0.261	0.190		0.041**	-0.127***	-0.018	0.309		
<i>Tsang et al. (2018): N2011 vs. Liu</i>											
N2011	-1.224***	2.603***	0.160	0.247	101	0.073***	-0.137***	-0.016	0.407	4.6	
Liu	-0.614	3.004***	0.050	0.231		0.068***	-0.146***	-0.007	0.402		
<i>Liu et al. (2007): N2011 vs. Shu</i>											
N2011						14.07***	-12.68***	-0.476	0.241	>1000	
Shu						8.084***	-15.44***	-0.507	0.194		
<i>Liu et al. (2007): N2011 vs. Liu</i>											
N2011						16.53***	-17.46***	-0.755	0.310	>1000	
Liu						14.16***	-19.74***	-0.207	0.296		
<i>Wang et al. (2020): N2011 vs. Shu</i>						<i>Wang et al. (2020) latency: N2011 vs. Shu</i>					
N2011	-0.031***	0.037***	0.005	0.198	>1000	0.155***	-0.170***	0.006	0.330	>1000	
Shu	-0.017***	0.042***	0.006	0.166		0.113***	-0.183***	0.003	0.289		
						<i>Wang et al. (2020) duration: N2011 vs. Shu</i>					
N2011						0.061**	-0.258***	0.047*	0.202	0.01	
Shu						0.087***	-0.246***	0.047*	0.208		
<i>Wang et al. (2020): N2011 vs. Liu</i>						<i>Wang et al. (2020) latency: N2011 vs. Liu</i>					
N2011	-0.044***	0.046***	0.002	0.257	>1000	0.161***	-0.200***	0.009	0.357	>1000	

Liu	-0.036***	0.050***	0.003	0.235			0.135***	-0.214***	0.011	0.335	
							<i>Wang et al. (2020) duration: N2011 vs. Liu</i>				
N2011							0.067**	-0.252***	-0.032	0.190	3.8
Liu							0.057**	-0.258***	-0.031	0.188	

Table 4: Comparison between the 2011 norm and the 2001 norm in explanatory power (with character log frequency and number of meanings as co-variables).

Norm	Accuracy					Reaction time					
	AoA	Frequenc y	Meaning	R^2_{adj}	BF	AoA	Frequency	Meaning	R^2_{adj}	BF	
<i>Sze et al. (2014)</i>											
N2011	-0.010***	0.011***	-0.001	0.010	>1000	0.066***	-0.119***	-0.007	0.385	698	
N2001	-0.008***	0.012***	-0.000	0.090		0.063***	-0.120***	-0.008	0.381		
<i>Tsang et al. (2018)</i>											
N2011	-1.760***	2.589***	0.473	0.272	1.6	0.095***	-0.131***	-0.027*	0.432	0.18	
N2001	-1.733***	2.651***	0.371	0.271		0.098***	-0.132***	-0.021	0.436		
<i>Liu et al. (2007)</i>											
N2011						16.45***	-14.61***	-0.843	0.281	>1000	
N2001						14.65***	-15.55***	-0.964	0.266		
<i>Wang et al. (2020)</i>											
N2011	-0.048***	0.048***	0.000	0.288	>1000	0.193***	-0.201***	0.013	0.392	>1000	
N2001	-0.044***	0.048***	0.002	0.274		0.185***	-0.199***	0.007	0.383		
<i>Wang et al. (2020): Duration</i>											
N2011						0.049**	-0.275***	-0.038*	0.212	2.8	
N2001						0.042**	-0.277***	-0.040*	0.211		

