MODEL

We follow the framework of Krishna et al. 2022 to model student effort decisions. Without loss of generality, assume there is only one main subject and one selective subject. The main subject always adopts absolute grading, while the selective subject adopts either absolute or relative grading. For a representative student, achieving a raw score of t_M in the main subject and t_m in the selective subject requires effort levels of $c_M(t_M)$ and $c_m(t_m)$, respectively. Assume that both $c_M(\cdot)$ and $c_m(\cdot)$ are twice continuously differentiable with non-negative first and second derivatives, i.e., $c'_M(\cdot), c''_M(\cdot), c'_m(\cdot), c''_m(\cdot) \geq 0$, and satisfy $c_M(0) = c_m(0) = 0$.

The student's total Gaokao score is then given by $t_M + \phi(t_m)$, where the *transformation function* ϕ transforms the raw score t_m into the converted score $\phi(t_m)$. Specifically, when the selective subject adopts absolute grading, $\phi(t) = t$. That is, absolute grading is actually a special case of relative grading where the transformation is the identity function.

To characterize the heterogeneity of student ability, assume that each student belongs to a specific type x, where $x \in [0,1]$. Let $g_1(x)$ ($g_1(x) \geq 0$) represent the marginal utility of the Gaokao score, meaning that each additional point in the Gaokao score increases the student's utility by $g_1(x)$ units. Let $g_2(x)$ ($g_2(x) \geq 0$) denote the student's learning ability, such that the effort required for a student of type x to achieve a score of t in a subject is $\frac{c(t)}{g_2(x)}$. Without loss, assume $g_1(x) \cdot g_2(x) = x$ for any $x \in [0,1]$, as x can always be rearranged to satisfy this relationship. Additionally, assume that $g_1(x)$ is monotonically increasing in x, i.e., $g'_1(x) \geq 0$.

Let the cumulative distribution function of x be $F(x)$ and the density function be $f(x)$, such that $f(x) = F'(x)$. Assume that the distribution of x is symmetric, i.e., $f(x)$ is symmetric about $x = \frac{1}{2}$. Additionally, suppose $f(x)$ is monotonically increasing on $\left[0, \frac{1}{2}\right]$, i.e., $f'(x) \geq 0$ for all $x \in \left[0, \frac{1}{2}\right]$. These assumptions imply that the distribution of student ability follows a bell-shaped curve, with most students concentrated around the median and relatively fewer at both ends.

Under the above assumptions, the utility function of a representative student of type x is defined as:

$$U_{total}(t_M, t_m; x) = g_1(x) \cdot (t_M + \phi(t_m)) - \frac{c_M(t_M) + c_m(t_m)}{g_2(x)} \tag{A1}$$

The total effort exerted by all students is given by:

$$C_{total} = \int_0^1 \frac{c_M(t_M) + c_m(t_m)}{g_2(x)} f(x) \mathrm{d}x \tag{A2}$$

A1. Independence of Optimal Effort Choices In Two Subjects

PROPOSITION 1: *The optimal choices of t_M and t_m are separable. Specifically, the optimal study time on the main subject is independent of the grading system of the selective subject, and the optimal study time on the selective subject is independent of the grading system of the main subject.*

Intuitively, Proposition 1 suggests that a student maximizes their utility from the total Gaokao score as if separately maximizing the utility from the main subject and the selective subject. This result holds because, for a given type x, the student's utility is linear in the total Gaokao score, which is the sum of the main subject's score and the selective subject's converted score, and the effort costs to achieve these scores are also separable. Proof details are provided in Appendix B.B1.

By Proposition 1, the optimal choice of t_M is constant because the grading system of the main subject remains unchanged. This directly implies that the total effort in the main subject is always constant. Consequently, any change in the grading system of the selective subject affects total student effort solely through changes in effort in the selective subject. Therefore, we can focus exclusively on the selective subject. For clarity, we introduce the following notations:

$$U := g_1(x)\phi(t_m) - \frac{c_m(t_m)}{g_2(x)}, \quad C := \int_0^1 \frac{c_m(t_m)}{g_2(x)} f(x)\mathrm{d}x, \quad t := t_m \tag{A3}$$

A2. Effect of Granularity on Total Student Effort

Under relative grading, a student's score is determined by the rank order of her raw score, i.e., the relative position of her raw score among all students. Thus, the converted score can be expressed as $\phi(t, \boldsymbol{t}_-)$, where $\boldsymbol{t}_-$ represents the target raw scores of the selective subject chosen by all other students. Hence, the utility function U is given by:

$$U(t, \boldsymbol{t}_-; x) = g_1(x)\phi(t, \boldsymbol{t}_-) - \frac{c(t)}{g_2(t)} \tag{A4}$$

It is challenging to directly solve such a multi-player game for a Nash equilibrium. However, Olszewski and Siegel 2016's work on large contests demonstrates that this game can be approximated by a single-principal mechanism that directly assigns scores based on student type x from high to low. Specifically, almost all students of type x select the following target score:

$$t(x) = c^{-1}\left(x \cdot y(x) - \int_0^x y(\tilde{x})\mathrm{d}\tilde{x}\right) \tag{A5}$$

where the function $y(x)$ specifies score assignments ordered by student types, rather than following the transformation rule of the relative grading system.

Let $G(y)$ be the cumulative distribution function of the assigned scores. Then, $y(x)$ is an implicit function determined by the following relationship:

$$G(y) = F(x). \tag{A6}$$

This relationship indicates that the percentile of a student's type within the population equals the percentile of the score assigned to that student among all assigned scores. Define

$$G^{-1}(z) = \inf\{y \mid G(y) \geq z\} \tag{A7}$$

for $z \in [0, 1]$. Then, $y(x) = G^{-1}(F(x))$.

Consider a relative grading system with a full score of β [10] and a total of n grades ($n \in \mathbb{Z}$, $n \geq 2$). For simplicity, we assume in subsequent discussions that the score difference between any two adjacent grades is constant and that each grade interval contains the same number of students.

Denote the target raw score chosen by a type x student at equilibrium as $t_n(x)$, the total student effort in the selective subject as C_n, and the cumulative distribution function of the transformed scores as G_n, with $y_n(x) = G_n^{-1}(F(x))$. Then we have:

$$G_n^{-1}(z) = \beta\frac{i}{n-1}, \ \forall i \in 0, 1, \ldots, n-1, z \in \left[\frac{i}{n}, \frac{i+1}{n}\right). \tag{A8}$$

Naturally, we assume without loss that the student of the highest type is assigned with the full score, i.e.,

[10] Theoretically, if we focus solely on the selective subject, the full score can always be normalized to 1 and is thus unnecessary. However, in this setting, the main subject also contributes to the total score and adopts a different grading system, making it necessary to define the full score of the selective subject. In Gaokao's practice, while each selective subject nominally contributes 100 points to the total Gaokao score of 750, some relative grading systems ensure that the lowest converted score is not 0, but 40 instead. In such cases, the effective full score—the range of scores that influences student incentives—is only 60.

$G_n^{-1}(1) = \beta$. Then, C_n can be expressed as:

$$C_n = \int_0^1 \frac{c(t_n(x))}{g_2(x)} f(x)\mathrm{d}x \tag{A9}$$
$$= \int_0^1 g_1(x) y_n(x) f(x)\mathrm{d}x - \int_0^1 \frac{f(x)}{g_2(x)}\mathrm{d}x \int_0^x y_n(\tilde{x})\mathrm{d}\tilde{x}$$

PROPOSITION 2: *C_n is monotonically decreasing with respect to n.*

Proposition 2 implies that, within relative grading systems, as granularity increases, the total student effort in the selective subject decreases. The proof of Proposition 2 is provided in Appendix B.B2.

A3. Total Effort Under Absolute vs. Relative Grading

Finally, we are going to compare the total effort under absolute grading versus that under relative grading. As shown in Equation (A9), the total effort in the selective subject under relative grading system with n grade intervals is given by:

$$C_n = \int_0^1 g_1(x) y_n(x) f(x)\mathrm{d}x - \int_0^1 \frac{f(x)}{g_2(x)}\mathrm{d}x \int_0^x y_n(\tilde{x})\mathrm{d}\tilde{x}.$$

When the selective subject adopts absolute grading, the transformation function is actually $\phi(t) = t$, which means the raw score is exactly the transformed score. Under absolute grading, denote the optimal choice of t as t_0, and the total student effort in the selective subject as C_0. Then, the utility function for a type x student is given by:

$$U(t;x) = g_1(x)t - \frac{c(t)}{g_2(x)} \tag{A10}$$

By first-order condition, the optimal choice of t_0 for a student of type x satisfies:

$$t_0(x) = c'^{-1}(x) \tag{A11}$$

Thus, the total effort in the selective subject under absolute grading, C_0, is:

$$C_0 = \int_0^1 \frac{c(t_0(x))}{g_2(x)} f(x)\mathrm{d}x = \int_0^1 c(c'^{-1}(x))\frac{f(x)}{g_2(x)}\mathrm{d}x \tag{A12}$$

The total effort under absolute grading (C_0) and relative grading (C_n) cannot be directly compared due to several factors, including the undetermined full score β, the number of grades n, and the functional forms of the cost function $c(\cdot)$ and the type distribution $f(\cdot)$. Thus, we consider different choices β and n based on real-world Gaokao grading systems, together with appropriate specifications of $c(\cdot)$ and $f(\cdot)$. Then, we run simulations to predict whether the relative grading system reduces total student effort compared to absolute grading.

In particular, we set $c(t) = \frac{1}{2}t^2$. For the type distribution $f(\cdot)$, we consider two distinct forms: (a) uniform distribution on $[0,1]$, denoted as $f(x) := f_{\mathscr{U}}(x) = 1$; and (b) trimmed normal distribution derived from $\mathscr{N}\left(\frac{1}{2}, \sigma^2\right)$ restricted to $[0,1]$[11], denoted as $f(x) := f_{\mathscr{N},\sigma}(x)$. And we consider $f_{\mathscr{N},\frac{1}{2}}$ ($\sigma = \frac{1}{2}$) and $f_{\mathscr{N},\frac{1}{6}}$ ($\sigma = \frac{1}{6}$), respectively.

[11] Denote the probability density function of $\mathscr{N}\left(\frac{1}{2}, \sigma^2\right)$ as $z_\sigma(\cdot)$, and its cumulative density function as $Z_\sigma(x)$. By trimmed normal distribution, we mean for any x in $[0,1]$, the probability density at x is $z_\sigma(x) + 2Z(0)$.

TABLE A1—SIMULATION RESULTS OF STUDENT EFFORT UNDER ABSOLUTE AND RELATIVE GRADING SYSTEMS

f	n	β	C_0	C_n	$\left(1-\frac{C_n}{C_0}\right)\cdot 100\%$
f_U	20	0.6	0.2500	0.1571	37.16%
		0.7		0.1833	26.68%
		0.8		0.2095	16.21%
		1		0.2618	-4.74%
	70	0.6		0.1521	39.16%
		0.7		0.1774	29.02%
		0.8		0.2028	18.88%
		1		0.2535	-1.40%
$f_{\mathcal{N},\frac{1}{2}}$	20	0.6		0.1630	34.82%
		0.7		0.1901	23.96%
		0.8		0.2173	13.09%
		1		0.2716	-8.63%
	70	0.6		0.1578	36.89%
		0.7		0.1841	26.37%
		0.8		0.2104	15.85%
		1		0.2630	-5.18%
$f_{\mathcal{N},\frac{1}{6}}$	20	0.6		0.2157	13.71%
		0.7		0.2517	-0.67%
		0.8		0.2876	-15.05%
		1		0.3595	-43.82%
	70	0.6		0.2112	15.53%
		0.7		0.2464	1.45%
		0.8		0.2816	-12.63%
		1		0.3520	-40.79%

Notes: This table presents the results of model simulations comparing total student effort under absolute and relative grading systems. f is the distribution of student types, n denotes the number of grades into which the relative grading system divides students, and β is the full score under the relative grading system. C_0 refers to the total effort under absolute grading, while C_n represents the total effort under relative grading with n grades. The column $\left(1-\frac{C_n}{C_0}\right)\cdot 100\%$ shows the percentage decrease in total student effort in the selective subject when transitioning from absolute grading to relative grading, with negative values indicating an increase in effort. The distribution of student types f is specified as f_U or $f_{\mathcal{N},\sigma^2}$, where f_U denotes a uniform distribution on $[0,1]$, and $f_{N,\sigma}$ represents a trimmed normal distribution $\mathcal{N}(0.5,\sigma^2)$ restricted to $[0,1]$, with $\sigma=\frac{1}{2}$ or $\sigma=\frac{1}{6}$. The cost function is specified as $c(t)=\frac{1}{2}t^2$. The full score β takes values of 0.6, 0.7, 0.8, and 1, respectively. The number of grade intervals n under the relative grading system is set to 20 or 70 to align with real-world grading practices in the Gaokao system.

Table A1 summarizes the simulation results, where $\left(1-\frac{C_n}{C_0}\right)\cdot 100\%$ represents the percentage decrease in total effort in the selective subject when changing from absolute to relative grading. The results indicate that relative grading systems generally reduces total effort compared to the absolute grading system across most parameter settings. For instance, when $(n,\beta)=(20,0.6)$—a scenario reflecting the Gaokao reform implemented in Beijing—the model predicts a 13.71% reduction in student effort under relative grading.

Therefore, based on the model and simulation results, we derive the following predictions. First, the change from absolute to relative grading in selective subjects affects student effort exclusively in those subjects, leaving effort in main subjects unchanged. Second, greater granularity in relative grading systems leads to lower total effort. Third, the relative grading systems implemented following the Gaokao reform are expected to reduce total student effort.

Mathematical Appendix

B1. *Proof of Proposition 1*

PROOF:

Let $U_M(t_M;x):=g_1(x)t_M-\frac{c_M(t_M)}{g_2(x)}$ and $U_m(t_m;x):=g_1(x)\phi(t_m)-\frac{c_m(t_m)}{g_2(x)}$. We can rewrite $U_{total}(t_M,t_m;x)$ as

$$\begin{aligned}U_{total}(t_M,t_m;x)&=g_1(x)\cdot(t_M+\phi(t_m))-\frac{c_M(t_M)+c_m(t_m)}{g_2(x)}\\&=\left(g_1(x)t_M-\frac{c_M(t_M)}{g_2(x)}\right)+\left(g_1(x)\phi(t_m)-\frac{c_m(t_m)}{g_2(x)}\right)\\&=U_M(t_M;x)+U_m(t_m;x)\end{aligned}\tag{B1}$$

This implies that the utility from the total Gaokao score can be split into two parts: the main subject and the selective subject.

To maximize the student's utility, t_M satisfies the first-order condition:

$$\begin{aligned}0&=\frac{\partial U_{total}}{\partial t_M}\\&=\frac{\partial U_M}{\partial t_M}+\frac{\partial U_m}{\partial t_M}\\&=\left(g_1(x)-\frac{c'_M(t_M)}{g_2(x)}\right)+0\end{aligned}\tag{B2}$$

Solving the first-order condition yields $t_M=c'^{-1}_M(x)$, which depends only on x and $c_M(\cdot)$. Similarly, we know that t_m satisfies $x\phi'(t_m)=c'_m(t_m)$, which only depends on x, c_m and $\phi(\cdot)$, namely the grading system on selective subjects.

Q.E.D.

B2. *Proof of Proposition 2*

PROOF:

Denote $I_1(n)$ and $I_2(n)$ as

$$I_1(n):=\int_0^1 g_1(x)y_n(x)f(x)\mathrm{d}x,\ I_2(n):=\int_0^1\frac{f(x)}{g_2(x)}\mathrm{d}x\int_0^x y_n(\tilde{x})\mathrm{d}\tilde{x}.$$

It suffices to prove that $I_1(n)$ is monotonically decreasing with respect to n, and $I_2(n)$ is monotonically increasing with respect to n.

For $I_1(n)$, taking the difference between $I_1(n)$ and $I_1(n+1)$ yields:

$$\begin{aligned}\Delta I_1(n) =& I_1(n) - I_1(n+1)\\ &= \int_0^1 g_1(x)y_n(x)f(x)\mathrm{d}x - \int_0^1 g_1(x)y_{n+1}(x)f(x)\mathrm{d}x\\ &= \int_0^1 g_1(G_n^{-1}(F(x)) - G_{n+1}^{-1}(F(x)))f(x)\mathrm{d}x\\ &= \int_0^1 g_1(F^{-1}(x))(G_n^{-1}(x) - G_{n+1}^{-1}(x))\mathrm{d}x\end{aligned} \tag{B3}$$

Let $h(x) = g_1(F^{-1}(x))$, then $h(x) > 0$ and is monotonically increasing with respect to x.

$$\begin{aligned}\Delta I_1(n) &= \int_0^1 h(x)(G_n^{-1}(x) - G_{n+1}^{-1}(x))\mathrm{d}x\\ &= \sum_{i=1}^{n-1}\int_{\frac{i}{n+1}}^{\frac{i}{n}} h(x)\beta\left(\frac{i-1}{n-1} - \frac{i}{n}\right)\mathrm{d}x + \sum_{i=1}^{n-1}\int_{\frac{i}{n}}^{\frac{i+1}{n+1}} h(x)\beta\left(\frac{i}{n-1} - \frac{i}{n}\right)\mathrm{d}x\\ &\geq \sum_{i=1}^{n-1}\int_{\frac{i}{n+1}}^{\frac{i}{n}} h\left(\frac{i}{n}\right)\beta\left(\frac{i-1}{n-1} - \frac{i}{n}\right)\mathrm{d}x + \sum_{i=1}^{n-1}\int_{\frac{i}{n}}^{\frac{i+1}{n+1}} h\left(\frac{i}{n}\right)\beta\left(\frac{i}{n-1} - \frac{i}{n}\right)\mathrm{d}x\\ &= \beta\sum_{i=1}^{n-1} h\left(\frac{i}{n}\right)\left(\left(\frac{i-1}{n-1} - \frac{i}{n}\right)\left(\frac{i}{n} - \frac{i}{n+1}\right) + \left(\frac{i}{n-1} - \frac{i}{n}\right)\left(\frac{i+1}{n+1} - \frac{i}{n}\right)\right)\\ &= \beta\sum_{i=1}^{n-1} h\left(\frac{i}{n}\right)\left(\frac{i(i-n)}{(n-1)n^2(n+1)} + \frac{i(n-i)}{(n-1)n^2(n+1)}\right)\\ &> 0\end{aligned} \tag{B4}$$

Thus, $I_1(n)$ is monotonically decreasing with respect to n.

For $I_2(n)$, taking the difference between $I_2(n)$ and $I_2(n+1)$ yields:

$$\begin{aligned}\Delta_{\text{latter}} &= \int_0^1 \frac{f(x)}{g_2(x)}\mathrm{d}x \int_0^x y_n(\tilde{x})\mathrm{d}\tilde{x} - \int_0^1 \frac{f(x)}{g_2(x)}\mathrm{d}x \int_0^x y_{n+1}(\tilde{x})\mathrm{d}\tilde{x}\\ &= \int_0^1 \frac{f(x)}{g_2(x)}\mathrm{d}x \int_0^x (y_n(\tilde{x}) - y_{n+1}(\tilde{x}))\,\mathrm{d}\tilde{x}\end{aligned} \tag{B5}$$

It suffices to show that $\int_0^x (y_n(\tilde{x}) - y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x} \leq 0$ holds for any $x \in [0,1]$.

For any $n \geq 2$, G_n^{-1} is symmetric about $\left(\frac{1}{2}, \frac{\beta}{2}\right)$, and F is symmetric about $\left(\frac{1}{2}, \frac{1}{2}\right)$, hence y_n is symmetric about $\left(\frac{1}{2},\frac{\beta}{2}\right)$. Thus, for all $a \in \left[0,\frac{1}{2}\right)$:

$$
\begin{aligned}
&\int_{\frac{1}{2}-a}^{\frac{1}{2}+a}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}\\
&=\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}+\int_{\frac{1}{2}}^{\frac{1}{2}+a}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}\\
&=\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}+\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_n(1-\tilde{x})-y_{n+1}(1-\tilde{x}))\mathrm{d}\tilde{x}\\
&=\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}+\int_{\frac{1}{2}-a}^{\frac{1}{2}}((\beta-y_n(\tilde{x}))-(\beta-y_{n+1}(\tilde{x})))\mathrm{d}\tilde{x}\\
&=\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}+\int_{\frac{1}{2}-a}^{\frac{1}{2}}(y_{n+1}(\tilde{x})-y_n(\tilde{x}))\mathrm{d}\tilde{x}\\
&=0
\end{aligned}
\tag{B6}
$$

Thus, it suffices to consider the case where $x \in \left[0,\frac{1}{2}\right]$.

For all $i \in \{1,2,\dots,n-1\}$, note that when $\tilde{x} \in \left(F^{-1}\left(\frac{i}{n+1}\right),F^{-1}\left(\frac{i}{n}\right)\right)$, we have:

$$y_n(\tilde{x})-y_{n+1}(\tilde{x})=\beta\cdot\left(\frac{i-1}{n-1}-\frac{i}{n}\right)<0 \tag{B7}$$

And when $\tilde{x} \in \left(F^{-1}\left(\frac{i}{n}\right),F^{-1}\left(\frac{i+1}{n+1}\right)\right)$, we have:

$$y_n(\tilde{x})-y_{n+1}(\tilde{x})=\beta\cdot\left(\frac{i}{n-1}-\frac{i}{n}\right)>0 \tag{B8}$$

Thus, it suffices to show that for all $i \in \{1,2,\dots,n-1\}$ and $F^{-1}\left(\frac{i+1}{n+1}\right)\le\frac{1}{2}$, we have:

$$\int_{F^{-1}\left(\frac{i}{n+1}\right)}^{F^{-1}\left(\frac{i}{n}\right)}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}+\int_{F^{-1}\left(\frac{i}{n}\right)}^{F^{-1}\left(\frac{i+1}{n+1}\right)}(y_n(\tilde{x})-y_{n+1}(\tilde{x}))\mathrm{d}\tilde{x}\le 0 \tag{B9}$$

Rewrite the left-hand side of Equation (B9) yields:

$$
\begin{aligned}
LHS=&\left(F^{-1}\left(\frac{i}{n}\right)-F^{-1}\left(\frac{i}{n+1}\right)\right)\beta\left(\frac{i-1}{n-1}-\frac{i}{n}\right)\\
&\qquad+\left(F^{-1}\left(\frac{i+1}{n+1}\right)-F^{-1}\left(\frac{i}{n}\right)\right)\beta\left(\frac{i}{n-1}-\frac{i}{n}\right)\\
=&\frac{\beta}{n(n-1)}\left(iF^{-1}\left(\frac{i+1}{n+1}\right)+(n-i)F^{-1}\left(\frac{i}{n+1}\right)-nF^{-1}\left(\frac{i}{n}\right)\right)\\
=&\frac{\beta}{n-1}\left(\frac{i}{n}F^{-1}\left(\frac{i+1}{n+1}\right)+\left(1-\frac{i}{n}\right)F^{-1}\left(\frac{i}{n+1}\right)\right.\\
&\qquad\left.-F^{-1}\left(\frac{i}{n}\cdot\frac{i+1}{n+1}+\left(1-\frac{i}{n}\right)\cdot\frac{i}{n+1}\right)\right)\\
\le&\, 0=RHS
\end{aligned}
\tag{B10}
$$

The last inequality in Equation (B9) is true from the assumption that $F''(x)=f'(x)\ge 0$ holds for any

$x \in \left[0, \frac{1}{2}\right]$.

Q.E.D

Analysis of CFPS Data

The China Family Panel Studies (CFPS)[12], initiated in 2010, is a nationally representative, biennial longitudinal survey of Chinese communities, families, and individuals. In its 2010 baseline survey, the CFPS successfully interviewed nearly 15,000 families and approximately 30,000 individuals within these families. The sample was drawn using a scientific stratification method, ensuring diversity in geographical distribution and richness in social contexts. CFPS collects comprehensive data across multiple domains, including education, economics, health, and family dynamics. As of now, the CFPS data has been updated through 2022.

This study focuses on the 2017 Gaokao reform implemented in two pivotal regions, Shanghai and Zhejiang, to examine how the shift from absolute grading to relative grading in selective subjects affects student effort. Specifically, we treat the reform as a quasi-natural experiment and employ the Difference-in-Differences (DiD) method to identify its impact on high school students' effort choices. Because a mainstream of Gaokao reform in other provinces was implemented in year 2021, we restrict our analysis to CFPS data up to 2020.

We estimate the following equation using ordinary least squares (OLS):

$$y_{it} = \beta_0 + \beta_1 \times reform_{it} + \beta_2 \times post_{it} + \beta_3 \times (reform_{it} \times post_{it}) + \gamma \boldsymbol{C} + \varepsilon, \tag{C1}$$

where y can be the study time measured in hours per week (*week*), per weekday (*weekday*), or per weekend (*weekend*). The variable $reform$ is dummy variable indicating if the observation is from a region affected by the 2017 Gaokao reform, and *post* is a dummy indicating if the observation is from a year following the reform. C includes control variables such as Gaokao year, sleep time, self-reported pressure, school ranking, family support, and others. The coefficient β_3 estimates the impact of the relative grading system on student effort.

Table C1— Impact of the 2017 Gaokao Reform on Study Time

Dependent Variables:	*week*	*weekday*	*weekend*
	(1)	(2)	(3)
$reform \times post$	-6.269	-1.066	-0.469
	(11.240)	(1.666)	(1.706)
Control Variables	Yes	Yes	Yes
Observations	1,697	1,697	1,697

Notes: This table reports the regression results estimating the impact of the 2017 Gaokao reform on students' study time using CFPS data. The dependent variables are weekly study time (*week*), study time per weekday (*weekday*), and study time per weekend (*weekend*), measured in hours. The key variable of interest is $reform \times post$, which captures the effect of the 2017 Gaokao reform on student study time. $reform$ is a dummy indicating observations from regions affected by the reform, and *post* is a dummy indicating observations from a year after the reform. Control variables include year factors, sleep time, self-reported pressure, school ranking, family support, and others. Heteroskedasticity-robust standard errors are reported in parentheses.

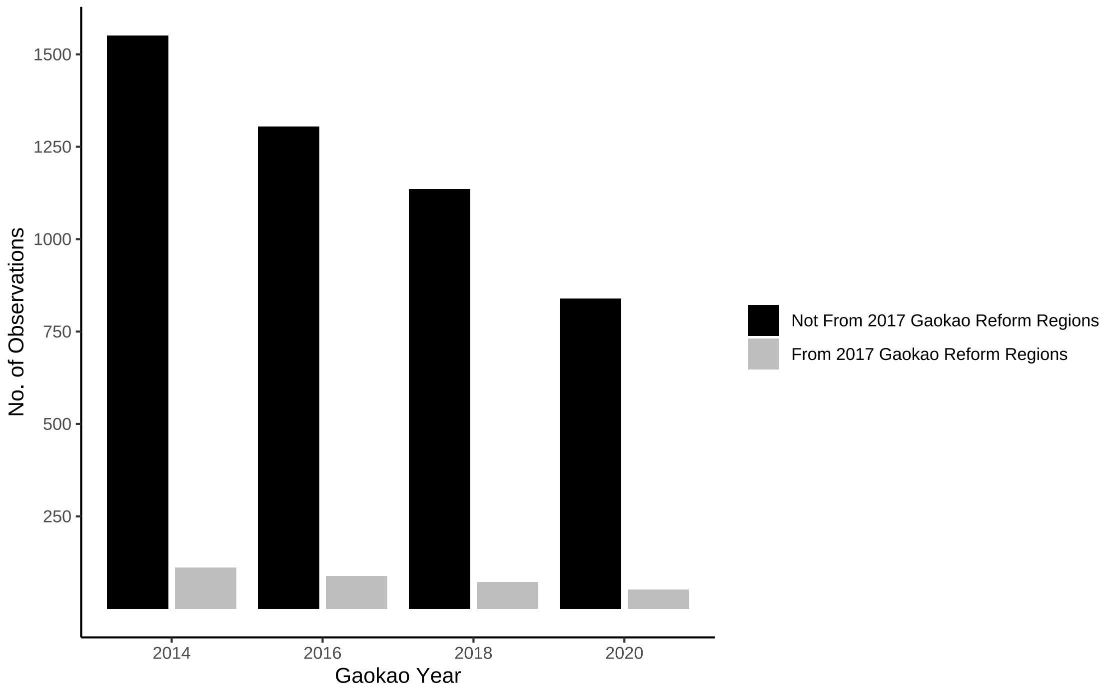
The regression results in Table C1 align with the model's predictions. The coefficients of $reform \times post$, the estimate of the 2017 Gaokao reform on student effort, indicate that the reform leads to an average decrease of 4.36 hours in students' weekly study time. Specifically, the reform reduces study time by 0.604 hours per weekday and 0.670 hours per weekend. While these coefficients are not statistically significant,

[12] The website for CFPS is available at https://www.isss.pku.edu.cn/cfps/en/, providing a more detailed introduction to the CFPS.

their magnitudes are economically meaningful. The lack of statistical significance can largely be attributed to the limited sample size of students affected by the Gaokao reform.

Although the CFPS theoretically tracks tens of thousands of families biennially, only 3% of the sample consists of high school students. Furthermore, since the 2017 Gaokao reform was implemented in only two pivotal regions, there is a significant disparity in sample size between reform and non-reform regions, as illustrated in Figure C1. This increases the variability of the estimates. Despite these limitations, the results are suggestive of the answer to our research question, indicating that the Gaokao reform reduces student effort.

FIGURE C1. SAMPLE SIZES OF HIGH SCHOOL STUDENTS IN 2017 GAOKAO REFORM AND NON-REFORM REGIONS



APPENDIX FOR QUESTIONNAIRE SURVEY

D1. Contents of the Questionnaire Survey

Survey on High School Student Study Mode for the Gaokao[13]

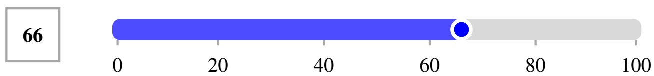
Thank you for participating in this survey!

This survey asks about aspects related to your subject choices and preparation for the Gaokao, such as your performances in different subjects and your time allocation on them. We will not ask for sensitive information such as specific scores or rankings.

Completing this survey is expected to take approximately **5 minutes**.

During the survey, you may encounter questions involving sliders:

[Sample Slider Question] How would you rate your proficiency in a given subject? / What is the proportion (%) of time you allocate to a given activity?



You may drag this slider to familiarize yourself with it.

For such slider questions, you can either directly input a number on the left or drag the slider to the desired position.

Click “Next Page” to begin.

[Page Break]

1) Which province did (or will) you take the Gaokao in? [Single Choice]

   Options: Shanghai, Zhejiang, Beijing, Tianjin, Shandong, Hainan, Hebei, Liaoning, Jiangsu, Fujian, Hubei, Hunan, Guangdong, Chongqing, Heilongjiang, Jilin, Anhui, Jiangxi, Guangxi, Guizhou, Gansu, Shanxi, Inner Mongolia, Shaanxi, Ningxia, Qinghai, Sichuan, Yunnan, Henan, Xinjiang, Tibet, Other (e.g., Hong Kong, Macao, Taiwan, overseas).

2) Which year did (or will) you take the Gaokao? [Single Choice]

   Options: 2015 or earlier, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024, 2025, 2026 or later.

3) Select your Gaokao mode[14]

   (3-1) Please determine whether the following statement is true: Your Gaokao policy follows the traditional Gaokao mode (in which you have to choose either the arts or science bundle). [Single Choice]

   Options: True, False.

   (3-2) Please determine whether the following statement is true: Your Gaokao policy follows the “3+3” mode[15] (If “False” in (3-1)). [Single Choice]

   Options: True, False.

[13]This survey was designed and implemented using the Wenjuanxing platform at https://www.wjx.cn.

[14] If it can be deduced from the Gaokao year and Gaokao province the respondent gives in the previous two questions that this province has implemented Gaokao reform at her Gaokao year, then (3-1) is displayed. If the province is going to implement “3+3” mode after Gaokao reform that had not been implemented at her Gaokao year, then (3-2) is displayed. If the province is going to implement “3+3” mode after Gaokao reform that had not been implemented at her Gaokao year, then (3-3) is displayed. These guarantees that any valid answer for this question must be “False.”

Based on the respondent’s reported province and year, the system determines the Gaokao policy in place at that time. Depending on the policy, one of the above questions is displayed, ensuring attentive respondents select “False” as the answer.

[15] “3+3” mode allows students to freely choose the three selective subjects out of six as they wish. The grading system under “3+3” mode is relative grading whose score difference between adjacent grades is 3. This corresponds to the *coarse* relative grading system.

(3-3) Please determine whether the following statement is true: Your Gaokao policy follows the 3+1+2 mode[16] (If "False" in (3-1)) . [Single Choice]

Options: True, False.

4) Subject Selection[17]

(4-1) What was your subject stream selection? [Single Choice]

Options: Arts, Science.

(4-2) What were your selected subjects? [Multiple Choice, Choose 3]

Options: History, Geography, Politics, Physics, Chemistry, Biology, (Technology).

5) During the school days in your senior year of high school, how much time did you spend on average each day preparing for the Gaokao? ______hours ______minutes.

This includes time spent in class, completing assignments, and additional practice.

6) During the weekends[18] in your senior year of high school, how much time did you spend on average each day preparing for the Gaokao? ______hours ______minutes.

7) Of the total study time mentioned above: The proportion spent on core subjects (Chinese, Mathematics, and Foreign Language) was approximately ______%; The proportion spent on selective subjects was approximately ______%. Please ensure that the two percentages add up to 100%.

The following questions will assess your proficiency and time allocation across six Gaokao subjects[19]. A good standard for your proficiency in each subject can be the percentile of this subject's score among the school in the most recent exam.

8) Regarding Chinese [Input a number between 0 and 100]

How proficient do you think you are in Chinese? ______

What proportion (%) of your study time is allocated to Chinese? ______

9) Regarding Mathematics [Input a number between 0 and 100] How proficient do you think you are in Mathematics? ______

What proportion (%) of your study time is allocated to Mathematics? ______

10) Regarding Foreign Language [Input a number between 0 and 100]

How proficient do you think you are in Foreign Language? ______

What proportion (%) of your study time is allocated to Foreign Language? ______

11) Regarding History [Input a number between 0 and 100]

How proficient do you think you are in History? ______

What proportion (%) of your study time is allocated to History? ______

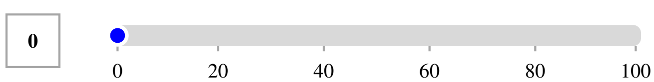
[16] "3+1+2" mode requires students to choose one from physics and history, and choose 2 subjects from chemistry, biology, geology and politics. The grading system under "3+3" mode is relative grading whose score difference between adjacent grades is 1. This corresponds to the *granular* relative grading system.

[17] If the respondent selects "True" for (3-1) or "False" for (3-2) or (3-3), (4-1) is shown; otherwise, (4-2) is displayed. The option "Technology" is only available for respondents from Zhejiang province.

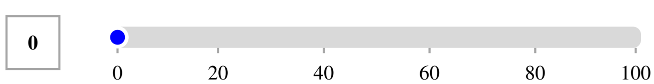
[18] Specifically, this refers to days that students do not need to go to school. It may not necessarily be the weekends, because some school have classes in weekends in practice. On the other hand, it includes holidays, winter or summer vacations, etc.

[19] Questions 11 to 17 will selectively appear only if the respondent indicates they have selected the corresponding subjects.

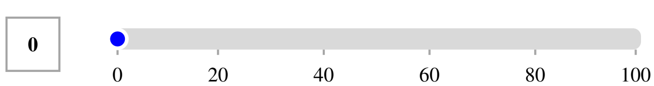
12) Regarding Geography [Input a number between 0 and 100]
    How proficient do you think you are in Geography? ______
    What proportion (%) of your study time is allocated to Geography? ______
13) Regarding Politics [Input a number between 0 and 100]
    How proficient do you think you are in Politics? ______
    What proportion (%) of your study time is allocated to Politics? ______
14) Regarding Physics [Input a number between 0 and 100]
    How proficient do you think you are in Physics? ______
    What proportion (%) of your study time is allocated to Physics? ______
15) Regarding Chemistry [Input a number between 0 and 100]
    How proficient do you think you are in Chemistry? ______
    What proportion (%) of your study time is allocated to Chemistry? ______
16) Regarding Biology [Input a number between 0 and 100]
    How proficient do you think you are in Biology? ______
    What proportion (%) of your study time is allocated to Biology? ______
17) Regarding Technology [Input a number between 0 and 100]
    How proficient do you think you are in Technology? ______
    What proportion (%) of your study time is allocated to Technology? ______
18) Do you believe you are significantly stronger in some subjects and weaker in others (i.e., a significant proficiency gap)? [Single Choice] Options: Yes, No.
19) What is your average daily sleep time (including naps)? ______hours ______minutes.
20) How often do you utilize fragmented time for studying (e.g., memorizing classical texts while waiting in line or learning vocabulary on the bus)? (0 indicates never using fragmented time to study, and 100 indicates always use fragmented time to study.)



21) To what extent do you think your family supported your Gaokao preparation in your senior year (e.g., better nutrients, extracurricular educational expenses, companionship)? (0 indicates no support, and 100 indicates fully support.)



22) How would you rate the amount of homework assigned by your school during your senior year? (0 indicates no homework, 100 indicates overwhelming amount of homework.)



23) During your senior year, how many exams did your school organize? ______times.

This includes exams such as weekly tests, monthly tests, midterms, finals that provide scores and rankings.

24) In your senior year, what percentage (%) of the students of your Gaokao year in your school do you believe you were academically stronger than? (0 indicates the weakest in the school, and 100 indicates the strongest.)

0

0 20 40 60 80 100

25) In your senior year, what percentage (%) of the students of your Gaokao year in your Gaokao province do you believe you were academically stronger than? (0 indicates the weakest in the province, and 100 indicates the strongest.)

0

0 20 40 60 80 100

26) What percentage (%) of schools in your Gaokao province do you think your school's overall Gaokao performance was stronger than? (0 indicates the weakest in the province, and 100 indicates the strongest.)

0

0 20 40 60 80 100

27) What was your level of academic pressure during your senior year? (0 indicates no pressure at all, and 100 indicates overwhelming pressure.)

0

0 20 40 60 80 100

28) In your senior year, what percentage (%) of senior students in your province do you think you face more pressure than? (0 indicates experiencing the least pressure in the province, and 100 indicates the greatest.)

0

0 20 40 60 80 100

29) Considering the difficulty of the Gaokao in your province, the number of competing students and their overall ability, and the number of available university seats, what percentage (%) of your peers nationwide do you think you faced more pressure for college admission than? (0 indicates experiencing the least pressure in the country, and 100 indicates the greatest.)

0

0 20 40 60 80 100

D2. Survey Sample

For a response to be considered valid, it must satisfy the following five data filtering criteria:

1) The respondent's Gaokao year and Gaokao province must match their reported Gaokao mode. (By design, a valid response corresponds to a "False" answer in the question asking the respondent to verify their Gaokao mode.)

2) The reported proportions of time spent on main subjects and selective subjects must sum to 100%.

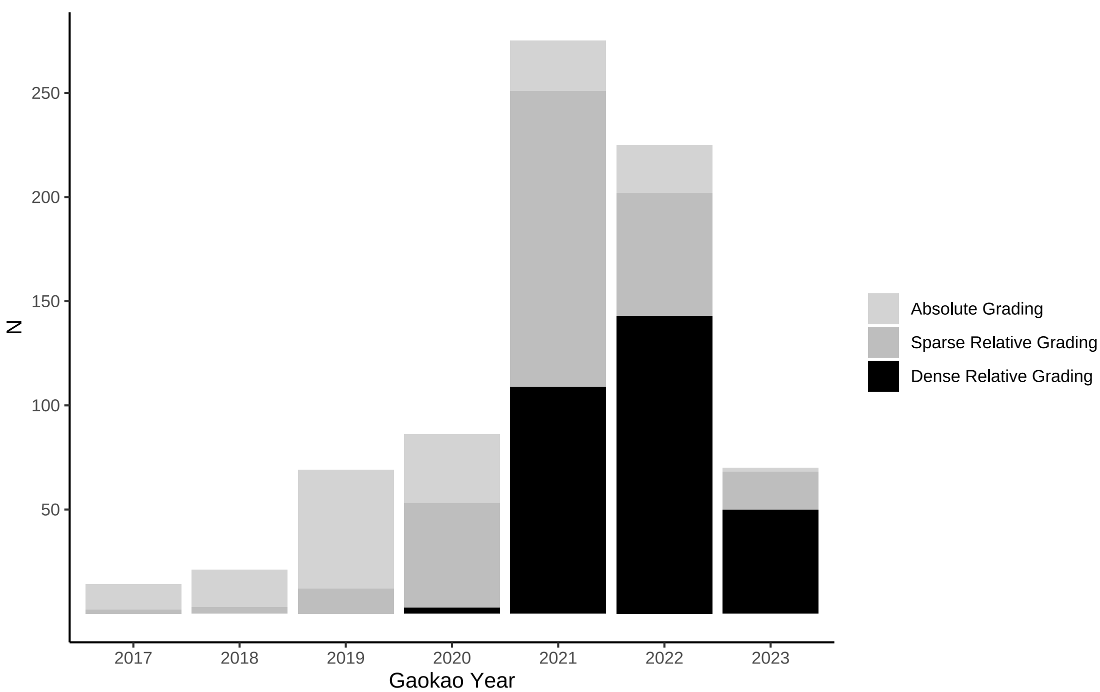
3) The respondent is not from Hainan, Hong Kong, Macao, Taiwan, or other regions where the Gaokao mode or college admission process differs significantly from the majority.

4) The respondent's Gaokao year must not be 2015, 2016, 2024, or 2025, as there are extremely few respondents from these years. Since year factors are controlled in the analysis, including such samples would obscure the year effect.

5) The respondent's answers must be logically reasonable. For example, one cannot report studying for 24 hours per day.

Initially, we received 1,196 responses, of which 760 met these criteria. Figure D1 presents the distribution of respondents by Gaokao year and grading system in selective subjects. Figure D2 illustrates the geographical distribution of respondents across China.

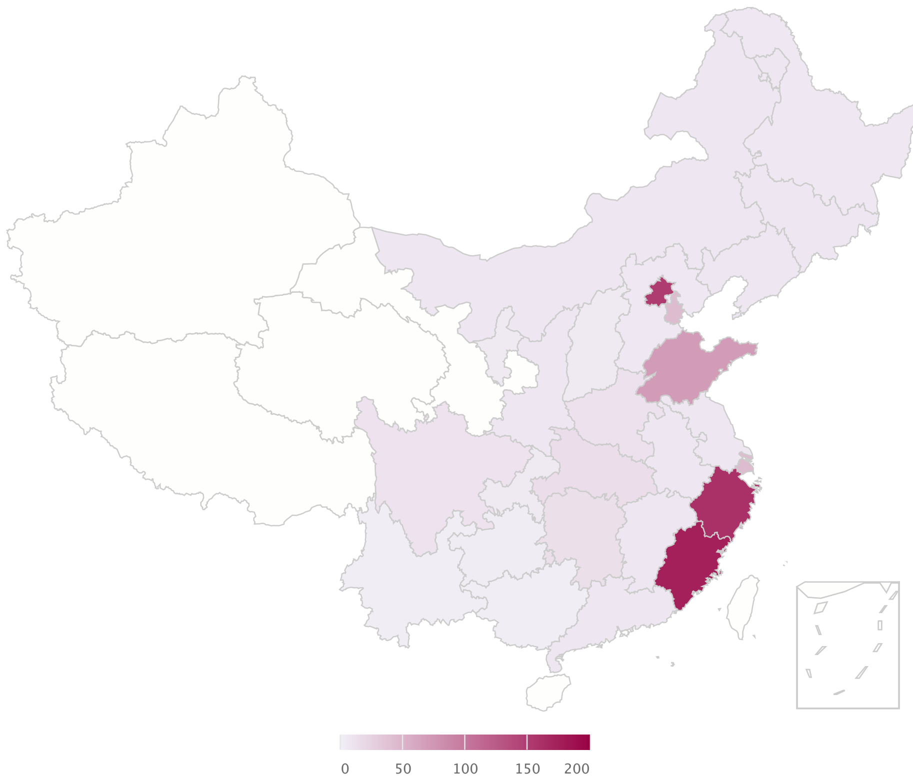
FIGURE D1. DISTRIBUTION OF RESPONDENTS BY GAOKAO YEAR AND GRADING SYSTEM IN SELECTIVE SUBJECTS



D3. Additional Analysis

We have demonstrate through the main results (see Section II.A) and heterogeneity analysis (see Section II.B) that the Gaokao reform reduces student effort. Building on these findings, we further explore its

FIGURE D2. GEOGRAPHICAL DISTRIBUTION OF SURVEY RESPONDENTS ACROSS CHINA



broader implications by examining how the reform affects students' self-reported pressure levels and sleep time. Specifically, we set y in Equation (1) and (2) as self-reported pressure level (*pressure*, ranging from 0 to 100) and daily sleep time (*sleep*, measured in hours), and estimate these equations using ordinary least squares (OLS). The regression results are presented in Table D1.

For self-reported pressure levels, the regression results reveal that the Gaokao reform significantly alleviates student pressure by around 5.41% ($p = 0.031$). This finding highly correlates with, and strongly supports our earlier results that the Gaokao reform leads to reduced student effort. The implication is that the relative grading system not only successfully makes students physically spend less time studying, but also makes them mentally feel less stressful.

For sleep time, the results show that the Gaokao reform, as well as both types of relative grading systems, has no significant impact. This finding, however, may not be a bad thing. It suggests that the time saved from reduced effort in selective subjects is likely redistributed to other daytime extracurricular activities, such as sports or music, which contributes to students' well-being. Notably, while the coefficient for Gaokao year (*year*) is negative and statistically significant, its magnitude is negligible. This indicates that high school students have already allocated nearly all their available time to studying. Although they attempt to reduce sleep time to study more, this strategy appears to have reached its limit. Thus, engaging in extracurricular activities becomes crucial for maintaining students' mental health, which highlights the broader implications of this finding.

APPENDIX FOR EXPERIMENT

E1. Experiment Manual

Thank you for participating this experiment!

TABLE D1— IMPACT OF GAOKAO REFORM ON PRESSURE LEVEL AND SLEEP TIME

Dependent Variables:	*pressure*		*sleep*	
	(1)	(2)	(3)	(4)
reform	-5.409		0.055	
	(2.509)		(0.093)	
granular		-4.185		0.043
		(2.923)		(0.109)
coarse		-6.136		0.062
		(2.611)		(0.098)
year	1.926	1.712	-0.085	-0.083
	(0.789)	(0.821)	(0.031)	(0.032)
Control Variables	Yes	Yes	Yes	Yes
Observations	760	760	760	760

Notes: This table presents the regression results for the impact of the Gaokao reform on self-reported pressure levels and daily sleep time. The dependent variables are self-reported pressure levels (*pressure*, ranging from 0 to 100) in Columns 1–2, and sleep time per day (*sleep*, in hours) in Columns 3–4. The variable *reform* indicates whether the respondent experienced the Gaokao reform, while *granular* and *coarse* represent granular and coarse relative grading systems, respectively. Control variables include Gaokao year, student ranking, self-reported pressure, the degree of imbalance between subjects, and other relevant factors. Heteroskedasticity-robust standard errors are reported in parentheses.

We are conducting a study to assess fundamental office skills. The experiment includes two tasks: *typing* and *mental arithmetic*. Your task is to test your typing speed and mental arithmetic skills. The experiment data and results will only be used for our research purpose. If you have any concerns, please feel free to contact the organizers.

To encourage you to perform at your best, we will additionally reward participants ranked in the top 2%–10% for their overall performance across both skills with **20** CNY per person, and those ranked in the top 2% with **100** CNY per person.

For both tasks, we take the best score for each subject, and you are allowed to make multiple attempts. It takes some time to get adapted to the specific contexts, so we encourage you to try multiple times.

Below is for Control group

Your overall score will be calculated as follows:

$$\text{Overall Score} = \text{Best Typing Speed (cpm)} + \text{Best Mental Arithmetic Score (points)}$$

(*Please answer this question for your understanding*) If a participant's best typing speed is 20 cpm and their best mental arithmetic score is 15 points, what is their overall score? ______

Note: We provide the correct answer of *35* after they submit the answer.

Below is for Dense group

Your overall score will be calculated as follows:

We will rank all participants' fastest typing speeds. Rankings will be divided into 11 categories, with the top 5%, 5%–15%, 15%–25%, ..., 85%–95%, and the bottom 5% receiving grades of A+, A, A-, B+, B, B-, C+, C, C-, D, and E, respectively. These grades correspond to scores of 20, 18, 16, ..., 2, and 0. This score will be added to your best mental arithmetic score (points) to determine your overall score. See the table below for details.

(*Please answer this question for your understanding*) If a participant's best typing speed is 20 cpm, their best mental arithmetic score is 21 points, and their typing speed ranks in the 30% percentile among all participants, what is their overall score? ______

Note: We provide the correct answer of *35* after they submit the answer.

Below is for Coarse group

Your overall score will be calculated as follows:

TABLE E1—GRADING RULE FOR GRANULAR GROUP

Rank	Grade	Score
Top 5%	A+	20
5%–15%	A	18
15%–25%	A-	16
25%–35%	B+	14
35%–45%	B	12
45%–55%	B-	10
55%–65%	C+	8
65%–75%	C	6
75%–85%	C-	4
85%–95%	D	2
Bottom 5%	E	0

We will rank all participants' fastest typing speeds. Rankings will be divided into 5 categories: Top 1/8, 1/8–3/8, 3/8–5/8, 5/8–7/8, and Bottom 1/8, which will receive grades of A, B, C, D, and E, respectively. These grades correspond to scores of 20, 15, 10, 5, and 0. This score will be added to your best mental arithmetic score (points) to determine your overall score. See the table below for details.

TABLE E2—GRADING RULE FOR COARSE GROUP

Rank	Grade	Score
Top 1/8	A	20
1/8–3/8	B	15
3/8–5/8	C	10
5/8–7/8	D	5
Bottom 1/8	E	0

(*Please answer this question for your understanding*) If a participant's fastest typing speed is 25 cpm, their highest mental arithmetic score is 20 points, and their typing speed ranks in the 2/8 fraction (i.e., 1/4), what is their overall score? ______

Note: We provide the correct answer of *35* after they submit the answer.

Below is the same for all groups

Please proceed to the following websites as instructed. If you encounter any technical or operational issues during the experiment, please feel free to contact the organizers.

1) Typing Test

   For the typing test, please use the website https://dazi.91xjr.com. Once you enter the site, you will see the following interface... (details omitted)[20].

2) Mental Arithmetic Test

   For the mental arithmetic test, please use the website https://www.preplounge.com/en/mental-math/add/1. Once you enter the site, you will see the following interface... (details omitted)[21]

[20] The details in the manual include instructions for using the typing test website. As it is lengthy and not essential, it is omitted.
[21] The details in the manual include instructions for using the mental arithmetic test website. As it is lengthy and not essential, it is omitted.

E2. Additional Results

Table E3 presents the comparisons of invested time between the control and granular groups, as well as between the control and coarse groups. The results generally align with the patterns observed in Table 4. Notably, the effect is more pronounced in the comparisons between the control and granular groups. In contrast, the coarse group shows less distinction from the control group. These findings are consistent with the model predictions: the granular relative grading system differs more markedly from the absolute grading system, as it is more effective in reducing effort compared to the coarse relative grading system.

TABLE E3—ADDITIONAL COMPARISONS OF INVESTED TIME: CONTROL VS. GRANULAR AND CONTROL VS. COARSE

	Panel A. Control and Granular Groups			
	Mean			
	Granular	Control	Difference	p-value
Time in Typing	6.111	9.000	-2.889	0.043
	(0.732)	(1.195)	(1.360)	
Time in Mental Arithmetic	4.806	6.265	-1.459	0.137
	(0.429)	(0.870)	(0.9705)	
Total Time	10.918	15.265	-4.347	0.034
	(1.012)	(1.742)	(2.015)	
Number of Subjects	39	42		
	Panel B. Control and Coarse Groups			
	Mean			
	Coarse	Control	Difference	p-value
Time in Typing	6.111	7.212	-1.788	0.278
	(0.732)	(1.195)	(1.635)	
Time in Mental Arithmetic	7.066	6.265	0.801	0.595
	(1.224)	(0.870)	(1.501)	
Total Time	14.278	15.265	-0.987	0.697
	(1.830)	(1.742)	(2.526)	
Number of Subjects	36	42		

Notes: This table presents comparisons of average time invested (in minutes) in typing, mental arithmetic, and total activities. Panel A reports comparisons between the granular group and the control group. Panel B compares the coarse group with the control group. The “Difference” column shows the mean differences between the groups. p-values are computed using a two-sample t-test, allowing for unequal variances.