The Correlation Between College Students' Interpersonal Skills and Their Entrepreneurial Performance

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Abstract—For college students, interpersonal skills (IS) are very necessary for them to build social networks and gain entrepreneurial resources, the level of their IS has a certain influence on their entrepreneurial performance (EP), and it's needful to explore the mechanism of such influence. For this reason, this paper studied the correlation between college students' IS and EP. At first, the paper gave a theoretical framework for analyzing the said influence mechanism. Then, focusing on the synchronization of IS and EP, this paper used the entropy to measure the sync correlation between the two, so as to quantify the joint improvement speed of the two, and six quantitative indicators had been adopted in the paper, including multi-scale sample entropy, multi-scale fuzzy entropy, cross-sample entropy, transfer entropy, de-trend correlation coefficient, and temporal correlation. At last, relevant experiments were conducted and the analysis results of the correlation between the two were given.

Keywords—interpersonal skills (IS), entrepreneurial performance (EP), correlation, synchronization, entropy

1 Introduction

Entrepreneurial Performance (EP) can measure the degree to which a college student completes a certain entrepreneurial task or achieve a certain entrepreneurial goal during the process of starting a new business, thus it has become an important indicator adopted by many studied for judging whether an enterprise created by student entrepreneurs is successful or not [1–5]. EP can be taken as a useful supplement to the entrepreneurial funds of the newly-started business created by student entrepreneurs, to a certain extent, it also represents the sufficiency degree of entrepreneurial capital [6–12]. EP is directly related to the profitability of the new business created by college students and the future development decisions made by student entrepreneurs, and a good EP is a key for the new business to maintain its competitive advantages in the market [13–16]. For student entrepreneurs, IS are a basic and necessary ability to build their social networks and gain entrepreneurial resources [17–21], therefore, IS have certain influence on EP, and it's needful to explore the mechanism of such influence.

Bian et al. [22] collected 421 samples from 20 entrepreneurial teams to construct a mediation moderation model from the perspective of conflict management and used it to test the roles of team diversity and team environment in moderating the relationship between entrepreneurial team and entrepreneurial performance. Wang et al. [23] proposed in their study that in the era of innovative big data, empirical data analysis can bring certain inspiration to firms, the authors collected first-hand data of 220 entrepreneurship enterprises in Shanghai, and employed the upper echelon theory and resource-based view to explore the relationship among entrepreneurial orientation, the ability of external resource acquisition (operational resource and intellectual resource), and the performance of new enterprises. Khalid [24] examined the role of artificial intelligence learning to promote entrepreneurship performance through entrepreneurial orientation and strategic entrepreneurship, and investigated the moderating role of government funding and attitude towards entrepreneurship. Kauffman and Kauffman [25] used a mixed method to assess the application period of an innovative interdisciplinary course in a world-class Russian University, and proposed some suggestions and implications to explain how to employ competency-based learning and self-efficacy for interpersonal skills in teaching and how to assess those content knowledge and pedagogical skills in contemporary education. Just [26] argued that in today's more participative work environments, it is more important than ever to have strong IS; the research of this paper showed that in workgroups or organizations, interpersonal skills that can affect teamwork and generate synergy effect, and it is a key factor for the selection of team leaders; the author also discussed several aspects of IS, including the values, self-concept, motivation, positive attitudes, behavior, trust & respect, communication, and awareness of personal style.

Currently, there're few studies on the correlation and causality between college students' IS and EP. Few scholars have paid attention to the influencing factors of IS and EP and their complex changes, and more emphases have been laid on the dynamic features of the fluctuations of EP. This paper holds that qualitative analysis is not enough for studying college students' IS and EP, so it explores the correlation between IS and EP, and the content of the paper is arranged as follows: the second chapter gave a theoretical framework for analyzing the influence mechanism of college students' IS on their EP. The third chapter discussed the synchronization of IS and EP, and used the entropy to measure the sync correlation between the two, so as to quantify their joint improvement speed, the six quantitative indicators adopted included multi-scale sample entropy, multi-scale fuzzy entropy, cross-sample entropy, transfer entropy, de-trend correlation coefficient, and temporal correlation. At last, relevant experiments were conducted and the analysis results of the correlation between the two were given.

2 The influence mechanism of college students' IS on EP

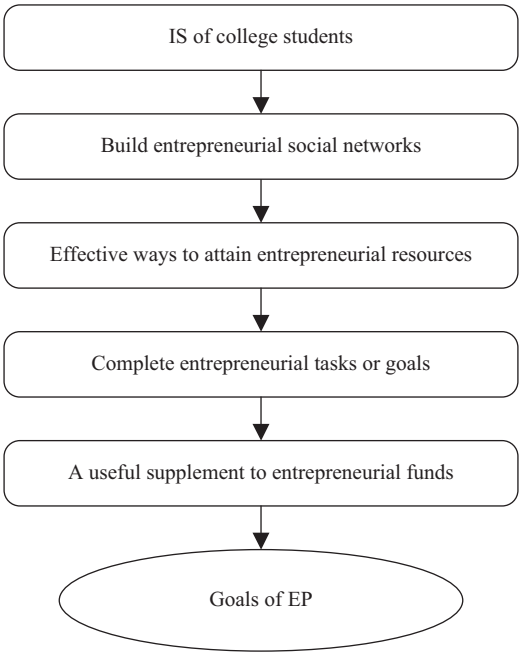

Fig. 1. A diagram of the influence of college students' IS on EP

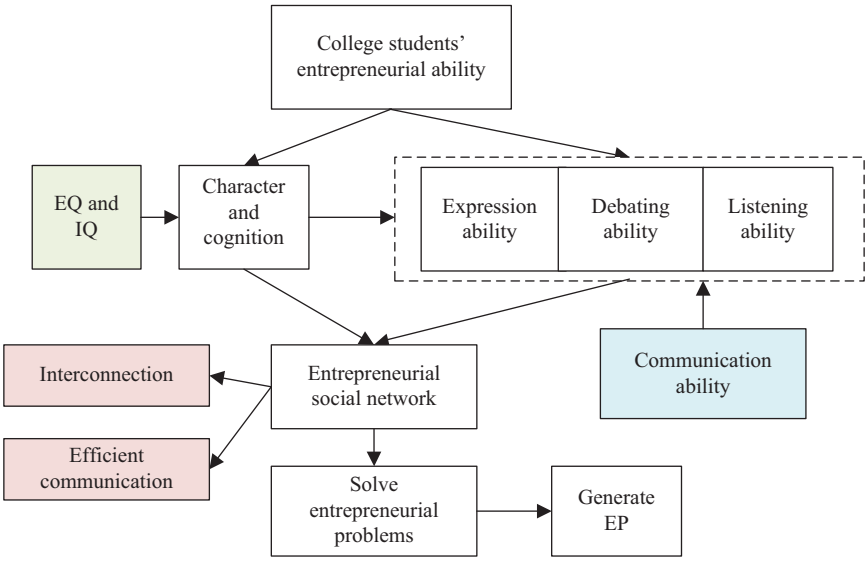

Fig. 2. Theoretical framework of the influence mechanism

Figure 1 gives a diagram of the influence of college students' IS on EP. Further analysis of EP showed that effective ways to attain entrepreneurial resources are the premise for completing entrepreneurial tasks and goals. For college students, all the resources of entrepreneurship they could attain are from their entrepreneurial social networks, and building such networks is determined by their IS, thus it can be known that, under the condition that the EP goals are remained unchanged, the better the IS of college students, the more entrepreneurial resources they could attain, and the higher the accomplishment degree of their entrepreneurial tasks and goals. Figure 2 gives a diagram of the theoretical framework of the influence mechanism. As can be seen from the figure, college students' EQ (emotional quotient), IQ (intelligence quotient), expression ability, debating ability, and listening ability are helpful for them to build entrepreneurial social networks, they can promote the information interconnection between college students and enterprises or institutions, and make the communication more efficient.

3 Correlation between IS and EP

This paper laid emphasis on the synchronization of college students' IS and EP, and used the entropy to measure the sync correlation between the two, so as to quantify their joint improvement speed. In addition, this paper conducted multi-scale analysis on students' IS and EP based on the multi-scale cross-sample entropy, and explored the correlation between the two from the perspective of time range and time scale integration.

To figure out the regularity of the data sequences of college students' IS and EP, this paper introduced the multi-scale sample entropy.

For a data sequence $A=\{a_1,a_2,...,a_L\}$ with a length of L, construct $L-k+n$ vectors $A_k(i)=\{a_i,a_{i+n},...,x_{i+k-1}\}$, $1\le i\le L-k+n$, and the dimension is k, then the Chebyshev distance $\delta_{i,j}$ between vectors $A_k(i)$ and $A_k(j)$ that represent the data of college students' IS and EP can be calculated by the following formula:

$$\delta_{i,j}\left[A_k(i),A_k(j)\right]=\max_{0\le m\le k-1}\left|a_{i+m}-a_{j+m}\right|,1\le i,j\le L-k,i\ne j \tag{1}$$

If the distance between the two vectors is within the range of tolerance s, then it's considered that the evolution laws of college students' IS and EP are similar. In this paper, assuming: Y_i represents the number of $A_k(j)$ similar to $A_k(i)$; X_i represents the number of $A_{k+1}(j)$ similar to $A_{k+1}(i)$; then, the local probabilities of the matching of vectors $Y^k_i(s)=Y_i/L-k-1$ and $X^m_i(r)=X_i/L-k-1$ were calculated, and the following formula calculates the global probabilities:

$$Y^k(s)=\frac{1}{L-k}\left(\sum_{i=1}^{L-k}Y_i^k(s)\right) \tag{2}$$

$$X^k(s)=\frac{1}{Y-k}\left(\sum_{i=1}^{L-k}X_i^k(s)\right) \tag{3}$$

If two data sequences of length L are within the range of tolerance s, then the negative natural logarithm of the conditional probability of the matching of point k can

be defined as the estimated value of the sample entropy, denoted as $SE(k, s, L)$, and its calculation formula is:

$$SE(k,s,L) = -ln\frac{X^k(s)}{Y^k(s)} \tag{4}$$

Multi-scale entropy provides a time-scale research perspective to evaluate the complexity of the data sequences of college students' IS and EP on different time scales. This paper adopted a moving average algorithm to get new sequences on a given time scale. Assuming: O represents the time scale; then the new sequence of sequence $A=\{a_1,a_2,...,a_L\}$ at time scale O can be expressed as:

$$B(i,O) = \frac{1}{O}\sum_{j=0}^{O-1} a_{i+j}, 1 \le i \le L-O+1 \tag{5}$$

Then, calculate the sample entropy of $B(i, O)$, and further get the multi-scale sample entropy of A.

In order to accurately measure the complexity and uncertainty of the real-time information of college students' IS and EP, this paper introduced the fuzzy entropy.

For a given sequence $A=\{a_1,a_2,...,a_L\}$, this paper defined a k-dimensional space and tolerance for it, which satisfy $k \le L-2$, after reconstructing the space, there is:

$$A_k(i) = \left\{a_i, a_{i+1}, ..., a_{i+k-1}\right\} - a_0(i), i = 1,2,...,L-k+1 \tag{6}$$

In the above formula, $a_0(i)=1/k\sum^{k-1}_{j=0}a(i+j)$ is the base point; let $m=0,1,...,k-1$ and $i \ne j$, then the distance e^k_{ij} between A^k_i and A^k_j can be calculated by the following formula:

$$e\left[A_i^k, A_j^k\right] + = \max_{0 \le m \le k-1}\left\{\left|a_{i+m} - a_0(i) - a_{j+m} + a_0(j)\right|\right\} \tag{7}$$

The fuzzy function can be expressed as:

$$E_{ij}^k(l,j) = exp(-(e_{ij}^k / s)^l) \tag{8}$$

Assuming: E^k_{ij} represents the similarity between A^k_i and A^k_j; s and l represent the similarity tolerance parameters, then the mean value of each i can be calculated by the following formula:

$$D_i^k(s) = \frac{1}{L-k}\sum\nolimits_{j=1, i \ne j}^{L-k} E_{ij}^k \tag{9}$$

The function of the k-dimensional average similarity can be expressed as:

$$\phi^k(l,s) = \frac{1}{L-k}\sum\nolimits_{i=1}^{L-k} D_i^k(s) \tag{10}$$

By repeating the above calculation steps, the k+n-dimensional average similarity $\varphi^{k+1}(l, s)$ can be attained. In this paper, the deviation of the natural logarithm of the

similarity of two consecutive dimensions was defined as the fuzzy entropy of the time series of college students' IS and EP, which can be calculated by the following formula:

$$FE(k,s,l,L) = ln\phi^{k}(s) - ln\phi^{k+1}(s) \tag{11}$$

The multi-scale fuzzy entropy of the time series of college students' IS and EP can be attained by processing the fuzzy entropy calculated by the moving average algorithm.

To measure the synchronization between two different time series of college students' IS and EP, this paper introduced the cross-sample entropy.

Given two parallel sequences of length L corresponding to the data of college students' IS and EP, $V=\{v_1,v_2,...,v_L\}$ and $U=\{u_1,u_2,...,u_L\}$, assuming k represents the vector length; s represents the tolerance level; at first, construct two vectors $A_k(i)=\{v_i,v_{i+1},...,v_{i+k-1}\}$ and $B_k(i)=\{u_j,u_{j+1},...,u_{j+k-1}\}$, wherein $1\le i,j\le L-k+n$, then the formula for calculating the distance between two sequence vectors is:

$$e_{i,j}\left[A_k(i),B_k(j)\right] = \max_{0\le m\le k-1}\left|v_{i+l}-u_{j+l}\right|, 1\le i,j\le L-k, i\ne j \tag{12}$$

Assuming: Y_i represents the number of vector $B_k(j)$ falling within the range of s near $A_k(i)$, then the local probability can be calculated based on the following formula:

$$Y_i^k(s)(u\,||\,v) = \frac{Y_i}{L-k} \tag{13}$$

Based on the calculation results of the above formula, the average value of local probabilities can be further calculated:

$$Y^k(s)(u\,||\,v) = \frac{1}{L-k}\left(\sum_{i=1}^{L-k} Y_i^k(s)(u\,||\,v)\right) \tag{14}$$

The global probability $X^k(s)(u||v)$ can be attained by embedding the calculated average value of local probabilities into size k+1, and the cross-sample entropy (CSE) can be calculated by the following formula:

$$CSE(k,s,L) = -ln\frac{X^k(s)(u\,||\,v)}{Y^k(s)(u\,||\,v)} \tag{15}$$

To figure out the causal relationship between the data sequences of college students' IS and EP, this paper introduced the transfer entropy. Given two dynamic entropy sequences V and U, assuming: $<>$ and ε respectively represent the mean and standard deviation of V and U, then following formula calculates the correlation coefficient of V and U based on entropy:

$$\eta_{VU} = \frac{\langle VU\rangle - \langle V\rangle\langle U\rangle}{\varepsilon V\varepsilon U} \tag{16}$$

The correlation relationships (positively correlated, not correlated, or negatively correlated) of the entropy value sequences of the data of college students' IS and EP

can be judged by the correlation coefficient. At time scale O, the transfer entropy of sequence B transferred to sequence A can be defined by the following formula:

$$TE_{B\to A}=\sum_{\Phi_A,\Phi_B} z(a_{o+1},a_o^{(m)},b_o^{(n)})log\left(\frac{z(a_{o+1}\mid a_o^{(m)},b_o^{(n)})}{z(a_{o+1}\mid a_o^{(m)})}\right) \tag{17}$$

Assuming: $a^{(m)}{}_o=(a_o,...,a_{o-m+1})$ and $b^{(m)}{}_o=(b_o,...,b_{o-m+1})$ are sequences with a length of m. During the calculation process of transfer entropy, the joint probability of a_{o+1}, $a^{(m)}{}_o$, and $b^{(m)}{}_o$ is represented by $RU(a_{o+1}, a^{(m)}{}_o, b^{(m)}{}_o)$; $RU(a_{o+1}|a^{(m)}{}_i, b^{(m)}{}_o)$ represents the probability that the condition is $a^{(m)}{}_o$ and $b^{(m)}{}_o$; $RU(a_{o+1}|a^{(m)}{}_o)$ represents the probability that the condition is only $a^{(m)}{}_o$. Φ_A and Φ_B represent the state spaces of A and B, they satisfy $a_{o+1}|a^{(m)}{}_o\in\Phi_A$ and $b^{(m)}{}_o\in\Phi_B$. Assuming: $z(a_{o+1}|a_o,...,a_1)=z(a_{o+1}|a^{(m)}{}_o)$ represents the deviation of sequence A from the generalized *Markov* property, then for the last n state of the given sequence B, the KL divergence can be used to measure $z(a_{o+1}|a_o,...,a_1)$.

To figure out the correlation between two parallel data sequences of college students' IS and EP, this paper introduced the de-trend cross-correlation coefficient; in order to obtain reasonable profiles, this paper integrated two time series $\{a_i\}$ and $\{b_i\}$ of length L as follows:

$$A(m)=\sum_i^m a_i, B(m)=\sum_i^m b_i, m=1,2,...,L \tag{18}$$

Let $L_r=L/r$, this paper divided the profile into $2L_r$ segments, and the de-trend value of the u segments of the profile can be calculated by the following formula:

$$A_{u,r(i)}=A(i)-A_{u,F}(i),(u-1)r<i\le ur \tag{19}$$

In the above formula, $A_{u,F}$ is the fitted value of the profile, the fitting can be performed by discrete linear polynomials, and the local de-trend covariance can be calculated by:

$$g_{ab}^2(u,r)=\frac{1}{r}\sum_{i=1}^{r}A_{u,r}((u-1)r+i)B_{u,r}((u-1)r+i) \tag{20}$$

This paper averaged all $2L_r$ segments and then calculated the de-trend covariance based on the following formula:

$$G_{ab}^2(r)=\frac{1}{2L_r}\sum_{u=1}^{2L_r}\left[g_{ab}^2(u,r)\right] \tag{21}$$

The de-trend correlation coefficient was defined as:

$$\sigma_{DCCA}(r)=\frac{G_{ab}^2(r)}{G_{aa}(r)G_{bb}(r)} \tag{22}$$

To figure out the temporal correlation features of the time series of the data of college students' IS and EP, this paper introduced the sliding window algorithm.

Assuming: θ represents the size of the sliding window; ξ represents the size of the sliding step; [.] represents the rounding operation; then for a given sequence $A=\{a_1,a_2,...,a_L\}$, the sliding window algorithm can be expressed as:

$$A_o = \left\{a_{1+o\xi},...,a_{\omega+o\xi}\right\}, 0 \le o \le \left[\frac{L-\theta}{\xi}\right], \xi \le \theta \le L \tag{23}$$

4 Experiment results and analysis

Table 1. Distribution of EP in different research regions

			Sample Size	Very Low	Low	Average	High	Very High
Region A	Full-Sample		13629	1.63%	7.58%	19.58%	51.46%	17.35%
	Goal theory	Task completion	4319	28.42%	30.24%	42.58%	37.69%	48.26%
		Profit	3926	30.63%	31.93%	33.68%	39.16%	25.68%
		Development prospect	2748	36.41%	34.61%	22.59%	22.35%	31.27%
	Resource theory	Resource type	6471	55.39%	59.26%	69.37%	55.38%	68.46%
		Resource scale	4692	47.19%	47.61%	31.27%	43.19%	31.58%
	Process theory	Behavior frequency	5937	57.13%	55.69%	50.37%	59.11%	43.61%
		Behavior level	5326	43.68%	41.31%	40.81%	47.25%	54.95%
Region B	Full-Sample		15284	1.35%	6.38%	13.62%	55.37%	12.58%
	Goal theory	Task completion	4185	23.57%	35.06%	36.29%	41.31%	42.51%
		Profit	3528	34.21%	39.25%	34.29%	37.62%	30.74%
		Development prospect	2039	31.02%	38.26%	27.53%	26.17%	16.39%
	Resource theory	Resource type	6529	42.51%	58.17%	64.31%	52.13%	62.37%
		Resource scale	4058	52.36%	40.25%	36.29%	45.62%	33.74%
	Process theory	Behavior frequency	5281	43.25%	48.57%	53.62%	41.36%	47.28%
		Behavior level	5192	54.74%	59.63%	46.25%	53.69%	50.37%

Table 1 shows the distribution of EP in different research regions. According to the statistics of Region A and Region B, among all samples in the research regions, samples with a "high" or "very high" EP accounted for more than 70%, indicating that the EP level of college students in the research regions was relatively high. In terms of the goal theory, the EP distribution data showed that, the completion degree of tasks with low EP levels was significantly lower than the profit and development prospect, and the completion degree of tasks with high levels was significantly higher than the profit and development prospect, and these indicated that, under the long-term action

of the guidance of colleges and the society, in terms of the goal theory, there're regional differences in the entrepreneurship development of college students, which reflected the laws of the variations in college students' IS and directly led to an improvement in the completion degree of tasks and goals, which was more significant than profit and development prospect. Judging from the perspectives of resource theory and process theory, the distribution of EP also showed that the proportion of "high" and "very high" resource types was much higher than that of the resource scale, and the proportion of "high" and "very high" behavior frequency was higher than that of the behavior level, which also verified the previous inference.

Table 2. Expression ability and EP

Variable		Verbal Expression Ability	Written Expression Ability	Graphical Expression Ability	Sample Size	*F-Value*	*Adj_R²*
Full-Sample		0.051**	0.036	0.0639*	13263	52.96	0.0241
Goal theory	Task completion	0.0528*	0.0526	0.0374**	4815	15.37	0.0251
	Profit	0.0285**	0.0417	0.0325***	3582	26.39	0.0241
	Development prospect	0.0417*	0.0512	0.2851**	2158	8.37	0.0215
Resource theory	Resource type	0.0552**	0.0258**	0.0527*	6121	42.35	0.0326
	Resource scale	0.0528*	0.0535	0.0362**	4362	15.28	0.0471

Table 3. Debating ability and EP

Variable		Response Ability	Oral Communication Experience	Expression Strategy	Sample Size	*F-Value*	*Adj_R²*
Full-Sample		0.0274***	0.0528**	0.0528*	14125	37.15	0.0542
Goal theory	Task completion	0.0528*	0.0625**	0.0374***	4725	16.37	0.0527
	Profit	0.0418	0.0241	0.0325*	3251	14.37	0.0629
	Development prospect	0.0248	0.0629	0.0639**	2417	7.61	0.0258
Resource theory	Resource type	0.0392**	0.0614***	0.0341	6142	23.51	0.0418
	Resource scale	0.0847	0.0528	0.0314**	4618	8.53	0.0274

Tables 2, 3, and 4 respectively show the correlation analysis results of college students' IS (including expression ability, debating ability, and listening ability) and their EP. According to Table 2, regardless of the full samples or partial samples, the coefficients of the three indicators of "verbal expression ability", "written expression ability" and "graphic expression ability" that measure the expression ability of college students were all positive, indicating that the expression ability of college students was

significantly positively correlated with EP. On the whole, the influence of expression ability on EP was increased, and both the full-sample and partial-sample data were valid. The data also showed that, in the influence of expression ability on EP, profit was greater than task completion and development prospect, and resource scale was greater than resource type.

Table 4. Listening ability and EP

Variable		Comprehensive Listening	Focused Listening	Analytical Listening	Sample Size	*F-Value*	*Adj_R*^{2}
Full-Sample		0.0417**	−0.0518*	0.0241**	14257	55.36	0.0418
Goal theory	Task completion	0.0285*	−0.0528*	0.0518***	4851	25.47	0.0362
	Profit	0.0612*	−0.0417**	0.0418	3519	1362	0.0481
	Development prospect	0.0857**	−0.1528*	0.0352	2417	13.62	0.0528
Resource theory	Resource type	0.0528*	−0.1622**	0.0367	6925	34.51	0.0472
	Resource scale	0.0845**	−0.0481*	0.0417	4172	16.39	0.0518

According to Table 3, the full samples and partial samples of different research regions showed that, the coefficients of the three variables of "response ability", "oral communication experience", and "expression strategy" were positive, indicating that college students' debating ability was significantly positively correlated with EP. In the data of full samples, the influence of college students' debating ability on EP became greater. From the perspectives of goal theory and resource theory, judging based on the data of partial samples, the EP effects of the three variables became stronger, namely the influence of college students' debating ability on EP increased, and the positive correlation between college students' debating ability and their EP can affect the entrepreneurial goals and entrepreneurial resources to a certain extent.

According to Table 4, in the data of full samples and partial samples, the coefficients of the three variables of "comprehensive listening", "focused listening", and "analytical listening" that measure the listening ability were all positive, that is, the listening ability of college students measured by these three variables had a significant positive influence on their EP, indicating that college students' social behavior during the process of starting the new business makes the entrepreneurship no longer the only purpose, but to build social networks with institutions and individuals with richer entrepreneurial resources. For student entrepreneurs, learning to listen can help them understand other people's meaning in a time manner, narrow the distance between entrepreneurs, thereby promoting the achievement of the entrepreneurial goals. In the data of full samples, the variables entrepreneurial goals and entrepreneurial resources had also passed the significance test, indicating that the two were also affected by the EP of college students' listening ability to a certain extent.

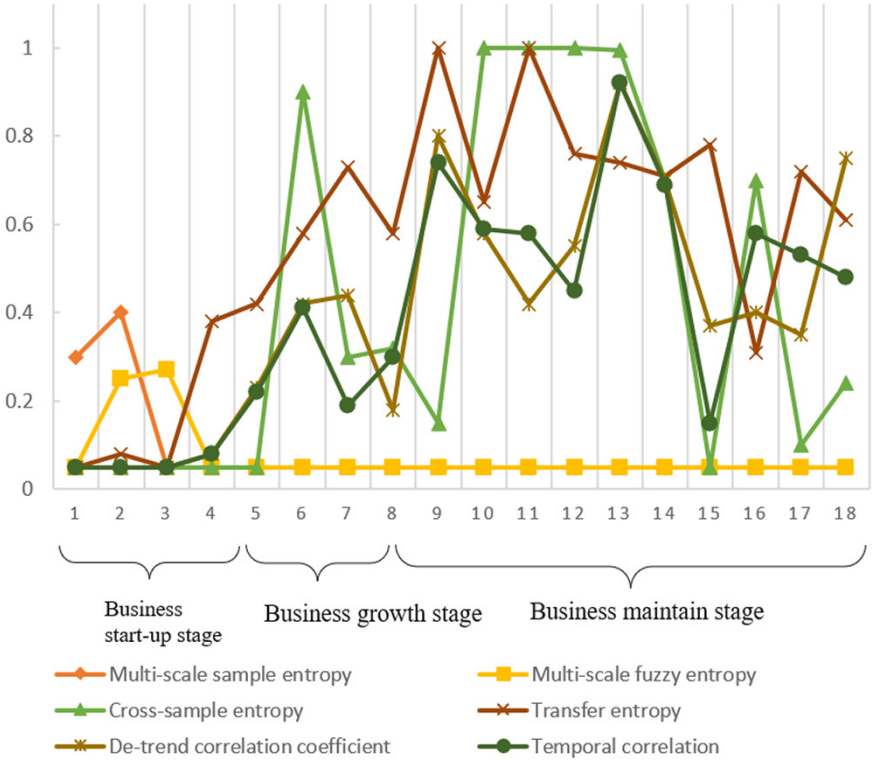

Fig. 3. Variation trends of different correlation analysis parameters in different entrepreneurial stages

The variation trends of the correlation analysis parameters of college students' entrepreneurship during the three stages (business start-up stage; business growth stage; business maintain stage) are shown in Figure 3. In the six parameters of multi-scale sample entropy, multi-scale fuzzy entropy, cross-sample entropy, transfer entropy, de-trend correlation coefficient, and temporal correlation, except for the multi-scale fuzzy entropy, the other five parameters all showed volatile rise with the advancement of the entrepreneurial stage. In the business growth stage, parameters reached the highest. In the business maintain stage, the parameters tended to be stale and maintained at the highest level. In the later part of the business maintain stages, the business matured and the parameters declined a bit. The reason is that, for student entrepreneurs, the main purpose of entrepreneurship is to attain EP, high EP can supplement entrepreneurial funds for them, the better the IS of student entrepreneurs, the more entrepreneurial goals they could achieve, and the higher the EP, which is consistent with the theoretical analysis results in previous texts.

5 Conclusion

This paper studied the correlation between college students' IS and EP. At first, this paper gave a theoretical framework for analyzing the influence mechanism of IS on EP. Then, focusing on the synchronization of IS and EP, this paper used the entropy to measure the sync correlation between the two, so as to quantify the joint improvement speed of the two, the six quantitative indicators adopted include multi-scale sample entropy, multi-scale fuzzy entropy, cross-sample entropy, transfer entropy, de-trend correlation coefficient, and temporal correlation. Combining with experiment, this paper gave the distribution of EP in different research regions, and analyzed the correlation between EP and college students' specific IS aspects, including the expression ability, debating ability, and listening ability. After that, this paper plotted the trends of correlation analysis parameters in different business stages, and the results revealed that, the better the IS of college students, the more entrepreneurial goals they could achieve, and the higher the EP. The experimental results were in good agreement with the theoretical analysis.

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