# Are you looking to teach? Cultural, temporal and dynamic insights into expert teacher gaze.

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**Highlights**

- Teacher gaze show expertise differences in static and dynamic aspects of expertise.
- Teacher gaze efficiency revealed cultural differences.
- Dynamic measures supplement conventional static measures of teacher expertise.

**Abstract**

We know that teachers' gaze patterns affect student learning, that experts and novices differ in their gaze during teaching and that gaze patterns differ by culture in non-educational settings. However, teacher gaze research is limited to Western cultural contexts and largely to laboratory settings. We explored expert and novice teacher gaze in real-world classrooms in two cultural contexts: Hong Kong and the UK. Forty teachers wore eye-tracking glasses during teacher-centred activities. We analysed 'communicative gaze' (gaze during talking) and 'attentional gaze' (gaze during questioning). We compared static (i.e., aggregated) and dynamic (i.e., structural) measures across expertise and cultures. Expert teachers looked longer at students and showed greater gaze efficiency than novices did, during attentional and communicative gaze. Expert teacher gaze was also more strategically consistent. In terms of cultural differences, UK teachers displayed greater attentional efficiency whereas Hong Kong teachers displayed greater efficiency in their communicative gaze. Our research underscores the value of going beyond conventional static analyses for culturally sensitive gaze research.

*Keywords:* Teacher expertise, cross-cultural comparisons, real-world eye-tracking, state space grids, communicative gaze

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## 1. Introduction

An expert has "special skills or knowledge representing mastery of a particular subject through experience and instruction" (Ericsson, 2014, p. 508). Although teachers can display expertise in many different ways, teacher *gaze* is especially pertinent because of its notable role in human learning (Csibra & Gergely, 2009). Expert teaching practice can be identified by comparing experts with novices on measures obtained through process-tracing techniques (Ericsson, 2006; Ericsson & Simon, 1980), such as eye-tracking (Van Gog, Pass & van Merriënboer, 2005) and State Space Grid analysis (Hollenstein, 2013).

Research into expert teacher gaze has already revealed, among experts, a student-centred mentality (Wolff, Van den Bogert, Jarodzka & Boshuizen, 2014), greater efficiency in visual processing (Van den Bogert, Bruggen, Kostons & Jochems, 2014), greater visual flexibility (Wolff, Jarodzka, van dem Bogert & Boshuizen, 2016), and greater consistency in gaze distribution across the classroom (Cortina, Miller, McKenzie & Epstein, 2015; Van den Bogert et al., 2014) when compared with novices. However, investigations into expert teacher gaze are limited to attentional (i.e., information-seeking) processes, with little examination of the way teachers use gaze for communicative (i.e., information-giving) purposes. Yet, adult gaze is a primary way by which humans are born to learn (Gredebäck, Fikke & Melinder, 2010) and cognitions underlying gaze can be identified using co-occurring speech (McNeill, 1985). Accordingly, we made use of co-occurring speech (questioning for attentional gaze; lecturing for communicative gaze) and conducted the present study in settings where investigation of communicative gaze was possible: that is, in real-world classrooms.

Moreover, explorations of teacher expertise have been confined to single cultural settings (i.e., the West; cf. Gegenfurtner, Lehtinen & Säljö, 2011), making most conclusions regarding expertise on gaze ungeneralisable or simply conflated with the cultural aspects of gaze (e.g., Kelly, Miellet & Caldara, 2010). We therefore investigated expert teacher gaze also as a function of culture. Expert–novice differences in teacher gaze are purported to collapse in East Asian settings (Yamamoto & Imai-Matsumura, 2013). Yet, by *analysing* teacher gaze in more than one way, we anticipated uncovering expertise differences that have been concealed until now. Where the traditional, static perspective on gaze has failed to differentiate experts from novices, the dynamic perspective on teachers' gaze was expected to capture new aspects of expertise differences due to the contribution that process-tracing techniques have the potential to make (Ericsson, 2006).

## 1.1. Teacher Expertise

Attaining expertise puts the teacher at great advantage. Experts make better decisions, have greater respect for students and have deeper pedagogical knowledge among other strengths (Berliner, 2004). With teacher expertise comes influence on social processes in the classroom (Brekelmans, Wubbels & Van Tartwijk, 2005); with it also comes student achievement (Hattie, 2003). Classrooms are comparable with "nuclear power plants, medical emergency rooms [and] air traffic control" (Berliner, 2001, p. 478). As such, teachers operate within a high-pressured context, in which the superior memory (Saariluoma, 1991), complex yet accurate manoeuvres (Chassy & Gobet, 2011) and fast decision-making (Haider, Frensch & Joram, 2005) that characterise expert performance are a real advantage.

Culture changes the way in which teaching occurs. Hofstede (1986) proposed that cultures are either individualistic (i.e., independent) or collectivistic (i.e., inter-dependent). Moreover, individualistic (e.g., Western) classrooms will welcome confrontation, concentrate on each individual's learning processes and individuals speaking up in whole-class discussion. Collectivistic (e.g., East Asian) classrooms, on the other hand, will value whole-class harmony, emphasise learners' progress in performance and students mainly speaking up in smaller-group discussions (Hofstede, 1986). Indeed, teachers are required to cater for different learning preferences, depending on cultural inclinations. East Asian students value learning through abstract concepts and internal reflection, whereas Western students prefer concrete experiences and active experimentation (Joy & Kolb, 2009). In terms of Shulman's (1987) tripartite model of teacher expertise, East Asian teachers demonstrated superior subject knowledge and pedagogical content knowledge whereas Western teachers performed better in their general pedagogical knowledge (Zhou, Peverly & Xin, 2006). Given the documented East–West contrasts in teachers' values and expertise, we expected to see East–West differences in the way teachers would use their gaze.

### 1.2. Expertise in Attentional Gaze

In the West, expert teachers distribute their gaze more evenly across the classroom (Cortina et al., 2015). Cortina demonstrated this by collecting teacher gaze data in the classroom using eye-tracking glasses. The gaze data was then analysed using the Gini coefficient (Gini, 1921), a metric for distribution inequality: the higher the Gini index, the greater the inequality. Cortina found novice teachers to yield larger Gini coefficients than expert teachers did. Novice teachers were thus preoccupied with salient classroom events, whereas expert teachers allocated their attention comprehensively throughout the classroom.

Laboratory research in the West has correspondingly shown experts to gaze towards each classroom area more often—and for shorter durations—when compared with novices (Van den Bogert et al., 2014). Van den Bogert suggested that expert teachers require less time to process classroom events, which makes them more able to move on from each region at each point. For example, a clapping and waving student—a visually salient classroom area—absorbed the novice's attention for longer than the expert's visual attention. Together, attentional capacities enable experts to distribute their gaze evenly across every classroom area in a way that novices do not.

So far, the expert–novice distinction in teachers' classroom attention is emphatic among Western samples. In East Asia, however, these expert–novice differences are less applicable. Yamamoto and Imai-Matsumura (2013) conducted a study comparable with Van den Bogert et al. (2014) in Japan. In this contrasting cultural background, classroom management problems did not lead to expert–novice differences in visual attention. Rather, experts did not apparently notice classroom problems any more than novices did. Yamamoto concluded that East Asian expertise cannot be demonstrated through teacher gaze. While the definition of 'classroom problems' in Yamamoto's study is questionable (Wolff, Jarodzka, van den Bogert & Boshuizen, 2016), one might also question the *way* expertise is revealed and how it should be measured in East Asian teacher gaze: an issue that we address in the present paper.

**1.3. Expertise in Communicative Gaze**

In contrast to attentional gaze that is used for information-seeking, communicative gaze is used for information-giving. Social psychology has documented adult (or teacher) gaze to be part of a system of natural pedagogy whereby teachers' signalling behaviours—such as eye contact—function as part of an innate framework by which infants, even newborns, learn (Csibra & Gergely, 2009). Additionally, Western teacher gaze generally transmits positive messages of support to students (Frymier, 1994; Kerssen-Griep & Witt, 2012). As part of teachers' non-verbal immediacy (i.e., support; Richmond, Gorham & McCroskey, 1987), eye contact during teacher talk enhances students' perceptions of teacher authority (Richmond, 1990). Non-verbal teacher immediacy through gaze has been consistently associated with positive teacher evaluations (McCroskey, Richmond, Sallinen, Fayer & Barraclough, 1995). Higher achievement is also predicted by immediacy behaviours such as teacher gaze (Witt, Wheeless & Allen, 2004). Just as expert teachers use qualitatively different verbal discourse to what novices use (e.g., experts ensure thematic unity throughout teacher talk; Sánchez, Rosales & Cañedo, 1999), so Western experts send encouraging and supportive signals through gaze in a way that novices do not.

As with gestures (Kita, 2009), culture shapes the social signals contained within gaze. Outside of the education science literature, expressions of the same cognition have been related to different gaze directions across cultural populations. Whereas thinking is shown through upward gaze in the West, it is shown through downward gaze in East Asia (McCarthy, Lee, Itakura & Muir, 2008). Related is the culturally diverse salience of the eyes during emotional perception. East Asian representations of emotion give importance to the eyes, whereas Western representations of emotion focus on the eyebrows and the mouth (Jack, Caldara & Schyns, 2012), which suggests that East Asians are more emotionally affected by eye contact. Indeed, Akechi et al. (2013) found East Asian recipients of direct gaze significantly more likely to report negative experiences of arousal. For example, anger was detected from images of direct gaze (i.e., eye contact) significantly more often by East Asian observers than by Western observers. Thus, the effect of eye contact apparently elicits culturally dissimilar reactions. East Asian teachers can therefore be expected to use eye contact differently from Western teachers. East Asian teacher gaze is more likely to convey hostility to their students than it is to convey immediacy, as it would in the West.

### 1.4. Features of Expertise in Teacher Gaze

The present study examines features of expertise within teacher gaze (Sternberg & Horvath, 1995). By taking two different perspectives on teacher gaze (i.e., static and dynamic), we investigated teacher knowledge, efficiency, flexibility and strategic consistency in each, attentional and communicative, teacher gaze. It was through varying these analytic perspectives that we anticipated uncovering the cultural aspects of expert teacher gaze that likely exists but could not be uncovered through conventional means. To take the static perspective on teacher gaze entails conventional analysis, in which aggregated measures are compared between groups. To supplement the static perspective, we then employed dynamic analyses by exploring multiple behavioural streams over time (Granic, 2005).

#### 1.4.1. The Static Perspective: Duration Analysis

The first feature of teacher expertise, knowledge, was explored using the static perspective on teacher gaze. Static analysis involved comparing mean durations of gaze towards various targets as used by teachers of differing expertise. Indeed, gaze durations are longstanding measures of knowledge. Longer gaze durations reveal depth of cognitive processing (Kuperman, Bertram & Baayen, 2008), task-relevance (Mackworth & Bruner, 1970) and importance (Reingold, Charness, Pomplun & Stampe, 2001) of the viewed region. Longer gaze durations typify expertise in chess (Reingold et al., 2001), sport (Mann, Williams, Ward & Janelle, 2007), internet use (Ehmke & Wilson, 2007), and driving (Chapman & Underwood, 1998). Expert teachers in the West have already demonstrated their focus on students—the centrally relevant region—by giving significantly more focus on them than any other classroom region or event (Cortina et al., 2015; Livingston & Borko, 1989; Wolff et al., 2016). East Asian teacher gaze durations can be expected to reveal differing priorities in the classroom, given the cultural differences in education, attention and communication documented above.

### 1.4.2. The Dynamic Perspective: State Space Grid Analysis

We continued investigations by taking the dynamic perspective to expert teacher gaze as well. Through dynamic systems analysis, we supplemented the static totals of where teachers look by exploring multiple behavioural *streams* over time (Granic, 2005): namely, didactic and gaze behaviours. The state space grid (SSG; Hollenstein, 2013) is the dynamic systems technique that we presently employed to examine behavioural changes within each, attentional and communicative gaze. A state space contains all the possible combinations of two behavioural streams of interest to show *events* which, in the present study, are *didactic gaze events*. Each event is represented by a cell (Figure 1). We now outline the expertise-related capabilities of the SSG which we explored in the present research.

The second feature of teacher expertise—efficiency—was explored using attractor measures available from state space grids. Attractors are the most prevalent and stable events in a state space (e.g., Fogel, 1993; Granic & Lamey, 2002). Since attractor gaze types are the most prevalent, they are likely the most relevant to classroom teaching. In expertise terms, attractors can be understood as the most *efficient didactic gaze* that teachers can use. Experts demonstrate exceptional efficiency as they have automatised their performance of a recurring task to establish the most optimal approach to classroom teaching (Feldon, 2007, cf. Anderson, 1982). Expert efficiency has been shown in gaze both outside (Haider et al., 2005; Jarodzka, Scheiter, Gerjets & van Gog, 2010) and inside (van den Bogert et al., 2014) the teaching profession. Solutions regarded as the most efficient may vary between cultures, in accordance with cultural values (Sternberg, 2014). Indeed, teachers excel in differing aspects of the profession depending on their cultural setting (König, Blömeke, Schmidt & Hsieh, 2011; Zhou, Lam & Chan, 2012).

The third feature of teacher expertise—flexibility—was explored using transition entropy measures available through state space grids. Behavioural flexibility is another typical characteristic of teacher expertise. Experts respond more quickly and effectively to both consistently demanding (Taatgen, 2005) and unusual (Bilalić, McLeod & Gobet, 2008; Lehmann & Ericsson, 1996; Star & Newton, 2009) scenarios. Likewise, expert teachers are documented to readily display flexibility in response to unforeseen classroom events (Leinhardt & Greeno, 1986; Livingston & Borko, 1989). Gaze flexibility has been shown by expert teachers in the classroom (e.g., Cortina et al., 2015). Even greater gaze flexibility, however, may be found among East Asian experts, as the upper threshold for student-directed gaze comes sooner in such settings where eye contact must be employed with caution (Alston & He, 1997; Cheng & Borzi, 1997).

The fourth and final feature of teacher expertise—strategic consistency—was explored using dispersion measures available through state space grids. Experts across domains demonstrate consistent use of selective strategies (Ericsson, 2006). Novice teachers have already demonstrated that they employ effective strategies less readily than experts (Dogusoy-Taylan & Cagiltay, 2014). Experts are also more consistently focussed on student-centred needs when considering others' teaching (Wolff et al., 2014). Teacher gaze in East Asia, however, may display exceptional levels of consistency, since persistence is an East Asian characteristic (Imbo & Le Fevre, 2009). Together, while experts were expected to display greater strategic consistency on the whole, East Asian experts may display even more predictability when compared with their Western counterparts.

### 1.5. The Present Study

Educational researchers have made headway in showing expertise as a function of teacher gaze. Despite the centrality of gaze for human communication, however, only one study has gone beyond teacher gaze for attention to explore teacher gaze for communication (McIntyre, Jarodzka & Klassen, under review). In the present study, we continue investigations into expert attentional (i.e., information-seeking) and communicative (i.e., information-giving) gaze on a static, aggregated level (i.e., where teachers look) by exploring duration measures of teacher gaze; we extend these investigations by using state space srid (Hollenstein, 2013) analyses to examine how teachers dynamically organise their gaze. Specifically, we investigated three dynamic components of expertise in teacher gaze through the use of state space grids: attractors—the most *efficient* types of teacher gaze; gaze transitions—gaze *flexibility* within the same teaching act (e.g., attention); and gaze dispersion—the *strategic consistency* of how teachers use their gaze on the whole.

Through expert–novice comparisons, the present research aimed to ascertain the role of teacher expertise in predicting teacher gaze patterns. Culture was taken into account due to the evidence for its role in expert gaze patterns. Accordingly, the present hypotheses were as follows.

*Hypothesis 1:* Expert teacher gaze patterns will emerge that transcend culture. In both cultures, Hong Kong and the UK, experts will focus more on important classroom regions, namely students (Section 1.2), as shown by longer gaze durations towards students, greater gaze efficiency (i.e., focusing on classroom-relevant gaze types), greater gaze flexibility to respond to the classroom situation, and more consistent gaze strategies among experts than novices.

*Hypothesis 2:* Teacher gaze patterns will emerge that are culture-specific. Compared with the UK, Hong Kong teachers will display longer gaze durations towards classroom regions other than students due to differing teacher values (Section 1.1) and the added complexities of eye contact in East Asia (Section 1.3). Gaze efficiency may therefore be weaker and more flexible in Hong Kong. Teachers' gaze strategy in Hong Kong will also appear less consistent compared with the UK.

## 2. Method

### 2.1. Participants

Forty teachers participated: 20 from the UK; 20 from Hong Kong. Such a sample size is comparable with some eye-tracking studies (Cortina et al., 2015) and larger than others (MacDonald & Tatler, 2013, 2015). Schools were approached on the basis of their conformity with the national curriculum and if they consisted of the first to the fifth years of secondary education. One UK and two Hong Kong schools agreed to participate.

The cultural grouping for each teacher was based simply on whether they taught in the UK ('West') or Hong Kong ('East Asia'). This cultural comparison is supported by longstanding contrasts in the way education (e.g., Hofstede, 1986; Leung, 1995, 2014; Kennedy, 2002), human attention (Nisbett & Kiyamoto, 2005; Norenzayan et al., 2002) and non-verbal communication (Averill, Chon & Hahn, 2001; Soto, Perez, Kim, Lee & Minnick, 2011) take place in these cultural settings. Much East–West difference can be attributed to contrasting cultural inclination (i.e., individualism in the West vs. collectivism in East Asia, Hofstede, 1986; Kitayama, Mesquita & Karawasa, 2006; Triandis, 2001) and Confucianism in East Asian settings such as Hong Kong (Leung, 1995; Li, 2005; Pratt, Kelly & Wong, 1999).

In keeping with established expertise research designs (e.g., Herppich et al., 2015; Sheridan & Reingold, 2014; van Meeuwen et al., 2014), we identified what expert teacher gaze consists of by making expert–novice comparisons. In each cultural group, 10 experts and 10 novices were recruited. Experts were identified from among the participating school populations using the criteria described by Palmer, Stough, Burdenski and Gonzales (2005).

Palmer's expertise classification system is multi-faceted and comprises four criteria: (1) years of teaching experience, (2) teacher performance ratings, (3) social recognition of excellence (e.g., selection by senior leadership team as 'expert' for the present study), and (4) additional qualifications (e.g., extra school responsibilities, Masters-level qualifications). Novices, in turn, were those who least conformed to these criteria and, as far as possible, contrasted with the experts in these respects. That is, novices in this study were not necessarily newcomers to the teaching profession; rather, they were teachers in the same school as experts who contrasted most with the experts. Because experts scored statistically significantly higher than novices on all of these criteria when compared both across the whole sample (e.g., all experts vs. all novices) and within cultural groups (e.g., Hong Kong experts vs. Hong Kong novices) according to analyses of variance ($p$ = .01 to $p$ < .001), years' experience in teaching was not seen as the sole or primary criterion: rather it was only one of several equally important criteria for teacher expertise. Full demographic details are shown within Palmer's framework of expertise in Table 1.

### 2.2. Apparatus

We used Tobii 1.0 eye-tracking glasses to record teacher gaze. Data rate was 30Hz, making one key frame one thirtieth of a second. The eye-tracker comprised a nine-point calibration system. The glasses yielded a 640 x 480px video: 56 degrees horizontally, 40 degrees vertically. This eye-tracker made simultaneous recordings of the scene, audio and gaze. The same eye-tracker was used in both cultural settings.

### 2.3. Procedure

For each participating teacher the eye-tracker was calibrated at the start of the scheduled data collection period. To protect calibration accuracy, teachers were explicitly requested not to move their eye-tracker after calibration. Given that the present study focused on the gaze of teachers, teacher-centred sessions were chosen for eye-tracking because these were the most teacher-rich parts of lessons. Teacher-centred parts of learning are also least likely to differ across subjects, due to the narrow range of events that can take place, all of which is captured in our coding scheme (Section 2.4.1 and 2.4.2). Teacher gaze was therefore recorded in at least ten minutes of teacher-centred learning, which were comparable across cultures and expertise[1], regardless of teacher age or subject. Gaze behaviours were manually coded by playing the gaze replay at one-eighth of the real-time speed; didactic behaviours were manually coded using the gaze playback in real-time. Codes were applied comprehensively: that is, the full duration of the data was classified to constitute a specific gaze and didactic behaviour simultaneously. Codes thus changed—or were re-applied—whenever teacher (i.e., gaze or didactic) behaviour changed, in keeping with our moment-to-moment and online approach to coding.

## 2.4. Measures

### 2.4.1. Gaze behaviour

The coded gaze behaviours were *student fixation* (focused gaze at students; i.e., more than four key frames), *student scan* (i.e., four key frames or less; cf. Franchak, Kretch, Soska & Adolph, 2011; Hanley et al., 2015), *student material, teacher material, other* (i.e., non-student and non-instructional) and *unsampled* gaze (which were excluded from analysis). Gaze behaviour codes are represented on the *x*-axis of our state space grid (Figure 1). *Student gaze* incorporated student fixation and student scan (first two columns from the left in Figure 1). *Non-student gaze* consisted of student materials, teacher materials and 'other' gaze (e.g., window; first three columns from the right in Figure 1). *Student gaze* and *non-student*

[1] To illustrate that teacher age and subject do not diminish the role of expertise or culture, we compared models including and excluding these as covariates, and presently report the mean differences in effect sizes and p-values (with covariates – without covariates). Expertise (predictor 1): $\Delta\eta_p^2$=-.06, Δp=.03. Culture (predictor 2): $\Delta\eta_p^2$=-.007, Δp=.001.

*gaze* are therefore counterparts to each other; they are mutually exclusive and one cannot occur alongside the other.

### 2.4.2. Didactic Behaviour

Didactic behaviours included *address behaviour* (i.e., directly instructing students to change their behaviour), *attention* (i.e., student *or* teacher asking and answering questions; second row up in Figure 1), *communication* (i.e., teachers lecturing; third row up in Figure 1), *refer notes* (i.e., teacher referring to presentation slides or students' resources), *logistics* (e.g., teacher moving the presentation onto another slide). Didactic behaviour codes are represented on the *y*-axis of our state space grid (Figure 1). Together, gaze and didactic behaviours combined to form *didactic gaze*.

### 2.4.3. Didactic Gaze Events

State space grids were constructed using GridWare 1.15a (SSG, Lamey, Hollenstein, Lewis & Granic, 2004). To do this, observational data files were created for each participant to generate these grids. A 5×5 grid was thus generated, yielding 25 possible gaze states as our SSG comprised 25 cells in total. Gaze behaviours were plotted along the x-axis; didactic behaviours along the y-axis. Each axis thus represented one aspect of behaviour by the same teacher; each cell represented the co-occurrence of their gaze and didactic behaviours. On each axis, behaviours were plotted from the most to the least student-oriented, so that the intersection of the two axes was the most student-oriented state (i.e., *student fixation* vs. *address behaviour*). It was in this way that we strived to plot categorical variables together into one meaningfully coherent 'state space' of teachers' didactic gaze.

Each cell of the SSG (Figure 1) represents a *didactic gaze* state. Such a state consisted of a co-occurrence of gaze behaviour and didactic behaviour. Two didactic gaze types are of central interest in this paper: *attentional gaze* (i.e., information-seeking) was inferred from gaze behaviours that occurred during attention (i.e., teacher asking students questions); *communicative gaze* (i.e., information-giving) was inferred from gaze behaviours that occurred during communication (i.e., teacher lecturing). Thus, didactic codes have been used to identify the dominating cognition that underlies teacher gaze (i.e., attention vs. communication) for separate analyses of didactic gaze events that are largely distinct from each other.

Intra-observer reliability was checked by asking the coder to re-code the first two out of ten minutes for two members of each sub-group (e.g., Western novices). Intra-class correlation (ICC) was used because we analysed duration data (Kottner et al., 2011). Two-way random ICC (i.e., ICC[2]) was run because two separate ratings were conducted and compared (e.g., Bartko, 1976). The ICC between the first and second coding attempts, for these specific periods, was obtained. Our coder showed strong consistency when transformed versions of duration *totals* (Hallgren, 2012) were compared between Time 1 and Time 2 (ICC[3] = .82, 95% CI[.65, .90]). Transformed *durations per visits* showed excellent intra-observer reliability (ICC[3] = .92, 95% CI[.84, .96]).

Inter-observer reliability was also checked to ensure that the coding scheme itself was reliable: a different coder therefore coded the same clips. Inter-observer reliability on transformed duration *totals* was good (ICC[2] = .78, 95% CI[.59, .89]) and acceptable for transformed *durations per visit* (ICC[2] = .65, 95% CI[.33, .81]).

#### 2.4.4. Static Gaze Measures

We controlled for the differing quantities of gaze events among individual participants by analysing relativised duration measures of teacher gaze. Accordingly, *mean duration per visit* was exported rather than mean cell duration, with one ‘visit’ (or act; represented by a node in Figure 1) being one occasion of an event (which is more conceptual; represented by a cell in Figure 1) taking place. The static gaze measures that we analysed were therefore as follows. Static attentional gaze included *attentional student gaze* duration per visit (first two cells from the left in Row B, Figure 1), mean *attentional non-student gaze* duration per visit (first three cells from the right in Row B, Figure 1), mean *communicative student gaze* duration per visit (first two cells from the left in Row A, Figure 1), and mean *communicative non-student gaze* duration per visit (first three cells from the right in Row B, Figure 1). Together, *student gaze* and *non-student gaze* constitute one single dimension of expertise: namely, teacher knowledge.

### 2.4.5. Dynamic Gaze Measures

#### 2.4.5.1.Gaze Efficiency

To explore gaze efficiency, attractors, or the most prevalent and stable didactic gaze used across both, the UK and Hong Kong, were estimated visually first by eyeballing the SSG images (e.g., Figure 1). By visual inspection, the most visited areas of the state space are *address behaviour* during *student fixation*, *attention* during *student fixation* and *communication* during *student fixation*. *Communication* also takes place often during *teacher material gaze*, as do *refer notes* during *teacher material gaze*.

An empirical way of identifying attractors is through the 'winnowing' procedure which involved mean cell durations (Lewis, Lamey & Douglas, 1999): in essence, winnowing consists of computing the proportion of heterogeneity accounted for by the mean cell duration of each cell in the state space (Table 2). Through this iterative winnowing procedure (Lewis et al., 1999), two regions were identified to be most universal among all teachers: namely, (1) *attention* during *student fixation* (or attentional student fixations) and (2) *communication* during *student fixation (*or communicative student fixations).

Attractors can be interpreted as the most relevant teacher gaze—or, the most *efficient gaze* for classroom teaching. That is, the more teachers use these gaze types, the more they are sticking to task-relevant gaze, and therefore the more efficient they are. Specifically, the *strength of efficient gaze* was analysed by exploring, for each efficient gaze type, the *mean return time* (i.e., the 'stickiness' of the efficient gaze, or how long a teacher takes to return to the most efficient gaze type) as an outcome variable. The longer the mean return time, the weaker the efficient gaze (or the less efficient the teacher's gaze).

**2.4.5.2.Gaze Flexibility**

To explore gaze flexibility, transitional entropy values were obtained from GridWare (Lewis, Hollenstein et al., 2004) by identifying *student gaze* regions as the 'origin' and *non-student gaze* regions as the 'destination': we did this for attention (i.e., questioning, Figure 1, Row B) and for communication (i.e., straight talk, Figure 1, Row A). *Gaze flexibility* thus related to the elasticity by which teachers alternated between student and non-student gaze.

**2.4.5.3.Strategic Consistency of Teacher Gaze**

To explore dynamic properties of teachers' didactic gaze as a whole (i.e., the whole grid in Figure 1), we obtained whole-grid dispersion values (Hollenstein, 2013). In addition to attentional and communicative gaze, the dispersion value also accounted for gaze during occasions when teachers addressed students' behaviour (i.e., *address behaviour*), when they referred to learning materials (i.e., *refer notes*) and when they were carrying out logistics (i.e., *logistics*). Thus, dispersion was a measure of overall didactic gaze consistency: the higher the dispersion, the lower the *strategic consistency*. The dispersion measure ranges from 0 to 1, with 0 representing no variation (i.e., high strategic consistency) from one cell and 1 being maximum variation (i.e., low strategic consistency), with every cell visited equally.

## 3. Results

Results are organised according to features of teacher expertise: knowledge, efficiency, flexibility then strategic consistency. For each feature, attentional gaze results are reported before communicative gaze. For multivariate analyses, we ran multivariate analyses of co-variance. Since no assumptions were violated when data was transformed and sample sizes were equal across groups, Wilk's lambda was used to get a more powerful criterion and to accord research conventions (Tabachnik & Fidell, 2013). To maintain the multivariate approach to analysis, MANCOVA was followed up by multivariate discriminant analysis (Borgen & Seling, 1978; Warne, 2014) and qualitative descriptions of how each DV differs across expertise and culture. For univariate analyses, analysis of co-variance was conducted. To avoid over-stating the relationship between teachers' culture with their gaze (Grace-Martin, 2012; Keppel & Wickens, 2004), we also included class size as a covariate throughout.

Where necessary, measures were square-root transformed in order to meet linear model assumptions prior to analysis, especially to impose a normal distribution and ensure equality of variances (Levene's test, $p$ = .18 to .96, exc. sqrtDispersion[2]). Table 3 shows descriptive statistics of each variable before and after data transformation, with all means adjusted for the covariate. Within each cell of our study design, outliers among variables for each analysis were removed, with different teachers yielding outlying data. Due to the relatively small size of our sample, outliers were removed per analysis rather than per participant. Variables involving outliers were *attentional non-student gaze* with one outlier, *attentional gaze efficiency* with two outliers, *communicative gaze efficiency* with four

[2] sqrtDispersion values yielded a Levene's test result of p=.02, but no extreme or outlying values were detected for expertise/culture groups or expertise + culture sub-groups and variances were deemed acceptable on visual inspection in group (expert s.d. = novice s.d.; Hong Kong s.d. = UK s.d.) and sub-group (Hong Kong expert s.d. = .152, Hong Kong novices = .152, UK experts = .145, UK novices = .158) comparisons.

outliers, *attentional gaze flexibility* with one outlier and *communicative gaze flexibility* with two outliers. Descriptive statistics were obtained and statistical analyses were conducted after outlier removal.

**3.1.Static Gaze Measures**

First, we explored whether teachers use different quantities of mean *attentional student gaze* and *attentional non-student gaze* duration per visit. In attentional gaze, MANCOVA revealed that expertise was a significant predictor of attentional gaze (Figure 2), $F(2,33) = 8.46$, $p = .001$, Wilk's $\Lambda = .66$, $\eta_p^2 = .34$, as was culture, $F(2,33) = 3.69$, $p = .04$, Wilk's $\Lambda = .82$, $\eta_p^2 = .18$, but not the expertise × culture interaction ($p = .83$). When following up MANCOVA, discriminant analysis showed *attentional student gaze* and *attentional non-student gaze* to have three discriminant functions, with a combined $\Lambda = .22$, $X^2 = 52.38$, $p < .001$. After removal of the first function, the remaining functions stayed significant, $\Lambda = .68$, $X^2 = 13.28$, $p = .01$. The third function was not significant on its own ($p = .96$). The first function explained 81.77% of the variance (canonical $R^2 = .67$), the second 18.22% (canonical $R^2 = .32$), and the third .00% (canonical $R^2 = .00$). Wilk's lambda and canonical $R^2$ values suggest only two of the three functions to be important, which were likely to be culture (Function 1) and expertise (Function 2) according to the discriminant scatter plot (Figure 3). Reclassification of cases on group memberships was almost above chance (44-90%, with <50 being chance; see Table 4 for other discriminant statistics). In general, experts ($M = 2.36$s) used more *attentional student gaze* than novices ($M = 1.28$s), while UK teachers ($M = 2.55$s) used even more than Hong Kong teachers ($M = 1.08$s). Contrary expertise patterns but the same cultural differences were seen in *attentional non-student gaze*. Our hypothesis was therefore supported by both MANCOVA and discriminant analysis, that the two classifications of present interest—expertise and culture—are what counts in teachers' attentional gaze durations (per visit).

In communicative gaze, *communicative student gaze* and *communicative non-student gaze* duration per visit were used as static gaze measures. MANCOVA revealed communicative gaze durations per visit to be significantly predicted by expertise, $F(2,34) = 11.93$, $p < .001$, Wilk's $\Lambda = .59$, $\eta_p^2$=.41, and near-significantly by culture, $F(2,34) = 2.95$, $p = .07$, Wilk's $\Lambda = .85$, $\eta_p^2$=.15, but not the expertise × culture interaction ($p = .51$, Figure 4). When following up MANOVA, discriminant analysis showed *communicative student gaze* and *communicative non-student gaze* also to have three discriminant functions, with a combined $\Lambda = .20$, $X^2 = 56.73$, $p < .001$. After removal of the first function, the remaining functions stayed significant, $\Lambda = .60$, $X^2 = 18.43$, $p = .001$. The third function was not significant on its own ($p = .25$). The first explained 74.71% of the variance (canonical $R^2 = .66$), the second 23.86% (canonical $R^2 = .38$), and the third 1.44% (canonical $R^2 = .04$). Again, Wilk's lambda and canonical $R^2$ values suggested that the third function was negligible, leaving only two functions relevant, which again were likely to be culture (Function 1) and expertise (Function 2) according to the discriminant scatter plot (Figure 5). Reclassification of cases on group memberships was above chance (50-80%, with <50% being chance; see Table 5 for other discriminant statistics). In general, experts ($M$ = 1.51s) used more *communicative student gaze* than novices ($M$ = .77s), while UK teachers ($M$ = 1.16s) used even more than Hong Kong teachers ($M$ = 1.12s). Contrary expertise *and* cultural patterns were seen in *communicative non-student gaze*. As in attentional gaze durations per visit, MANCOVA and discriminant analyses supported our hypotheses that the two classifications of present interest—expertise and culture—are what counts in teachers' communicative gaze durations (per visit).

## 3.2.Dynamic Gaze Measures

### 3.2.1. Gaze Efficiency

In attentional gaze, ANCOVA revealed that *strength of gaze efficiency* was predicted by expertise ($M_{Expert}$ = 1.99s; $M_{Novice}$ = 2.99s), $F(1,33) = 12.89$, $p = .001$, $\eta_p^2$=.28, culture ($M_{HK}$ = 2.97s; $M_{UK}$ = 2.02s), $F(1,33) = 5.78$, $p = .02$, $\eta_p^2$= .15, but not the expertise × culture interaction ($p = .74$; Figure 6). In communicative gaze, ANCOVA demonstrated that *strength of gaze efficiency* was significantly predicted by expertise ($M_{Experts}$ =2.01s; $M_{Novices}$ = 3.80s; Figure 7), $F(1,30) = 35.39$, $p < .001$, $\eta_p^2$= .54, and by culture ($M_{HK}$ = 3.49s; $M_{UK}$ = 2.32s), $F(1,30) = 6.95$, $p = .01$, $\eta_p^2$=.19, but not the expertise × culture interaction ($p = .27$).

### 3.2.2. Gaze Flexibility

Attentional gaze flexibility was explored through gaze transitions (see Figure 8). ANCOVA found expertise to significantly predict *gaze flexibility* (i.e., gaze transitions; $M_{Expert}$ = 57.27; $M_{Novice}$ = 33.56), $F(1,34) = 5.27$, $p = .03$, $\eta_p^2$= .13, but not culture ($p = .18$) or the expertise × culture interaction ($p = .06$; Figure 6). Communicative gaze flexibility was also explored through gaze transitions. ANCOVA revealed expertise ($M_{Expert}$ = 29.30; $M_{Novice}$ = 54.06), $F(1, 33) = 4.46$, $p = .04$, $\eta_p^2$=.12, but not culture (p = .92) or the expertise × culture interaction (p = .11), to be significant in predicting communicative gaze flexibility (Figure 9).

### 3.2.3. Strategic Consistency

To explore the overall structural properties of teachers' didactic gaze in general, we examined whole-grid dispersion, where large dispersion values signified low *didactic gaze consistency*. According to ANCOVA, experts ($M$ = .83) showed significantly greater *didactic gaze consistency* (i.e., less dispersed) than novices ($M$ = .88), $F(1,34) = 7.30$, $p$ = .01, $\eta_p^2$=.18. Cultures did not significantly differ in *didactic gaze consistency* ($p$=.90); neither was the expertise × culture interaction significant in predicting *didactic gaze consistency* ($p$ = .79, Table 6).

## 4. Discussion

The aim of the present study was to consider teacher expertise in an important part of human learning and one primary way in which adults teach and students learn (Csibra & Gergely, 2009): namely, teacher gaze. By exploring teacher gaze in real-world classrooms, we were able to analyse teacher gaze for communication (i.e., information-giving), in addition to teacher gaze for attention (i.e., information-seeking). Expert teachers were shown to use significantly more student gaze and greater gaze efficiency during both attention and communication. Experts were also more attentionally flexible but showed greater *in*flexibility during communicative gaze. In addition, experts displayed greater strategic consistency than novices. Hypothesis 1 was therefore supported on all features of expertise. In terms of cultural differences, UK teachers used more attentional student gaze, whereas Hong Kong teachers used more communicative *non*-student gaze. Attentional efficiency was greater in the UK, while communicative efficiency was greater in Hong Kong. Cultural differences were thus found in gaze measures of teacher knowledge and efficiency, lending some support to Hypothesis 2. Through state space grid analysis, the present paper demonstrates the contribution that *dynamic* measures can make to investigations of teacher gaze. Specifically, efficiency, flexibility and strategic consistency were only demonstrable through dynamic measures of teacher gaze.

### 4.1. Expert Teacher Gaze

In both attention and communication, student-centredness among experts was shown by significantly longer durations of teacher gaze directed at students compared with that of novices. Novices, in turn, showed longer non-student gaze durations than experts.

Moreover, the most efficient (i.e., relevant) gaze type was student-oriented fixation in both attention and communication. Expert attentional gaze was also more flexible, suggesting a readiness to respond to students (cf. Castejón & Martínez, 2001) and their strategy was more consistent (cf. Leinhardt, 1989) than novices'.

As anticipated in Hypothesis 1, expertise differences in teacher gaze were significant: teacher gaze durations demonstrated expert teachers' priority (e.g., Mackworth & Bruner, 1970) of students' classroom experience over and above other aspects of classroom instruction (Reeve, 2009; Schempp et al., 1998). Communicative gaze durations towards students were likewise significantly longer among experts than novices—and novices conversely looked longer at non-student targets than experts. Communicative gaze duration analyses thus highlighted expert teachers' awareness and application of natural pedagogical mechanisms (Csibra & Gergely, 2009) and efficient demonstration of communicative intent (Frith & Frith, 2012), both of which involve student-centredness. As in other professions, the present study has demonstrated that expertise in teaching also involves stronger efficiency (cf. van Merriënboer et al., 2002), attentional flexibility (cf. Bilalić et al., 2008) and strategic consistency (cf. Chase & Ericsson, 1982)—with the strategy likely to be student-centredness.

We also found novices to display greater communicative gaze flexibility than experts, unlike in attentional gaze. Expertise in communicative gaze thus appears to be characterised by *in*flexibility, or at least fewer transitions between students and non-student targets. Other analyses have highlighted student-centredness among experts: it may be this importance of maintaining eye contact with students while teachers are giving information (i.e., during communication) that explains experts' communicative gaze inflexibility. Indeed, expectations in natural pedagogy are such that teacher–learner eye contact is integral, before teachers' gaze shifts will be followed to make shared attention toward the pedagogical areas of interest successful (Frith & Frith, 2012; Senju & Csibra, 2008). The next step for understanding this is sequential analysis of teacher communicative gaze, which would confirm whether greater variety in communicative gaze occurs in gaze sequences and what the content of these sequences are, on top of the transition between student and non-student targets. Regardless of the explanation for the inflexibility in experts' communicative gaze, expert–novice emerged nonetheless and Hypothesis 1 has been supported.

### 4.2. Culture-Specific Teacher Gaze

Contrary to expectations, culture-specific *expertise* was not found in the present analyses. However, as expected in Hypothesis 2, *cultural differences* in teacher expertise were found. UK teachers looked more at students during attentional gaze; Hong Kong teachers looked more at *non*-student regions during communicative gaze. It was not surprising that Hong Kong teachers looked less at students than UK teachers did, given the cultural implications of looking 'too much' at students since eye contact becomes excessive or negative much sooner in East Asian contexts than Western settings (e.g., Cheng & Borzi, 1997). Since student-centredness is likely to be a teacher priority that transcends culture, it was not surprising if Hong Kong teachers deliberately reduced their eye contact with students, given the culture-specific signals of hostility associated with it. Our expectations were also confirmed when attentional gaze efficiency was greater in the UK than in Hong Kong, while communicative gaze efficiency was greater in Hong Kong than in the UK. This cultural difference in efficient gaze during each, attention and communication, aligns with preceding research that highlight more frequent use of teacher talk during classroom instruction in East Asian settings when compared with Western classrooms (Leung, 1995, 2014). It is likely that teachers become more efficient at the didactic activity that they are more accustomed to, hence UK teachers being more efficient at gaze during question-answering (i.e., attentional gaze) and Hong Kong teachers being more efficient with their gaze during talking in particular (i.e., communicative gaze).

**4.3.Limitations**

A number of limitations should be acknowledged for the present research. The discriminant function model that emerged in relation to attentional gaze durations per visit was at chance-level. This means that we cannot be confident that the two functions identified, expertise and culture, fully explained our data. Additionally, there may be debate regarding whether one can truly compare teacher expertise across cultures, given the culture-dependent nature of professional expertise especially teaching (Hofstede, 1986). However, the ‘social recognition’ criterion in Palmer et al.’s (2005) classification is likely to have addressed this critique, since school leaders will have put forward teachers whom colleagues regarded highly in accordance with their cultural values. Nevertheless, our sample was designed to address expertise as a multi-dimensional construct: future studies might delve deeper in the specific role of teacher *experience* as a sole factor in teacher gaze.

The statistical power may have been limited by our sample size and the intensive data-collection. The modest sample size may have contributed to the limited significance of our interaction term (i.e., expertise × culture) as well as chance-level discriminant function analysis for attentional gaze durations per visit. When we ran post-hoc power analysis using G*Power (Erdfelder, Faul & Buchner, 1996), for the MANOVA prediction of attentional student and non-student gaze duration per visit by expertise and culture, the statistical power using our effect size observed ($\eta_p^2$= .34) and sample size ($N$ = 40) was determined to be $\beta$=.99, which satisfied the standard $\beta$=.80 power requirement. Indeed, as reported above, noteworthy expertise and cultural main effects were found. It is therefore likely that expertise and culture simply do not interact but coincide in another way which can subsequently be investigated. On another note, a more conservative approach to outlier removal could have been taken if the sample had been larger, whereby an outlying data-point produced by one participant entails the removal of the participant from all analysis.

The analyses in our paper are limited to five didactic behaviours and five gaze behaviours. Indeed, five codes for gaze behaviours is also a limited reflection of the range of behaviour types that one can look at in the classroom and the didactic codes are not grounded in preceding theory and literature. However, we contend that five of each, didactic and gaze behaviours, in one state space has created a relatively large state space compared with other state space grid studies carried out across the disciplines (e.g., Dishion, Nelson, Winter & Bullock,, 2004; Granic & Lamey, 2002; Murphy-Mills, Bruner, Erickson & Côté, 2011) and no existing framework meets our purposes for the division of our didactic behavioural data. That is, existing frameworks are either too detailed on the micro-level (e.g., the categories of teacher talk by Leinhardt, 1989; the 'address behaviour') or relates to behaviours that are too much on the macro-level (e.g., the development of teacher lifestyles with expertise by Berliner, 2001). Thus, our state space was balanced parsimony with authenticity in its representation of real-world teacher gaze.

Ours was a highly naturalistic study. Other than Cortina et al. (2015), no published research on teacher expertise has brought eye-tracking into the classroom itself. However, limitations of real-world research apply to the present paper. Contrary to what is possible in laboratory studies, the precise nature of the 'teacher-centred' activity that we sampled could not be standardised across all participants for us to derive gaze patterns in relation to exactly the same instructional processes. Likewise, only the dominating cognition could be identified since conflicting cognitions (e.g., attention *and* communication) can occur simultaneously in real-world social behaviour. Still, this study took an opportunity to investigate teachers' attentional gaze in greater detail than in the past (cf. Cortina et al., 2015) and pioneered investigations into communication through teacher gaze—which would not have been possible in the laboratory. We would call for future research to continue innovating methodological designs that tease apart differing cognitions in teacher (and other professional) gaze.

**4.4.Implications**

Our findings may be of interest to teacher training programmes in various cultural contexts. In terms of attentional gaze, East Asian teacher education can explore attentional gaze flexibility with teacher trainees: increased gaze transitions between student and non-student classroom areas may prove more effective for classroom management. Beginning teachers might thus benefit from resembling expert teachers more during their interactions with students. In terms of communicative gaze, prospective teachers in East Asia could practise limited used of non-student gaze. Rather than giving misguided advice (e.g., to 'make as much eye contact as possible at all times'; cf. Leung, 2014), teacher-training programmes can underscore the empirically documented marks of expertise. The role of deliberate practice at implementing these behaviours should also be emphasised (e.g., Ericsson & Lehmann, 1996).

Specific to educational research, the present paper has highlighted the benefits of supplementing static with dynamic aspects of teaching in identifying good practice. If only conventional—static—comparisons were made in teachers' attentional gaze, then the East Asian marker of expert teacher gaze would not have been identified. Through flexibility analyses, East Asian expert–novice differences have been uncovered in the dynamic interaction between the student-oriented and non-student-oriented gaze behaviours, during teacher–student interacting (i.e., teacher attention). An implication from our paper is therefore to call for more dynamic analyses of effective teacher behaviour, as a supplement to continued static, aggregated measures.

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## Tables

Table 1

*Teacher Demographics*

| | | Student age (years) | | | | Subject | | | | Teacher details | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | Age | | Gender | | Years' experience | | | | Perf Ratings | | Add Quals | |
| Group | N | *M* | *SD* | Min | Max | Sci/ Maths | Native lang | Hum | Other | *M* | *SD* | M | F | *M* | *SD* | Min | Max | *M* | *SD* | *M* | *SD* |
| HK | | | | | | | | | | | | | | | | | | | | | |
| Expert | 10 | 14.00 | 1.41 | 12 | 16 | 0 | 4 | 4 | 2 | 44.00 | 9.94 | 3 | 7 | 19.30 | 7.47 | 10 | 32 | 1.60 | .84 | 2.70 | 1.49 |
| Novice | 10 | 13.30 | 1.77 | 12 | 16 | 2 | 1 | 4 | 3 | 26 | 3.16 | 3 | 7 | 4.60 | 3.24 | 1 | 10 | 2.70 | .95 | 1.10 | 1.10 |
| UK | | | | | | | | | | | | | | | | | | | | | |
| Expert | 10 | 12.20 | 1.23 | 11 | 14 | 2 | 0 | 7 | 1 | 35.00 | 8.16 | 4 | 6 | 11.00 | 7.36 | 3 | 28 | 1.20 | .42 | 2.10 | .74 |
| Novice | 10 | 11.82 | 1.08 | 11 | 14 | 3 | 2 | 4 | 2 | 33.00 | 10.33 | 4 | 6 | 3.23 | 2.48 | 2 | 10 | 2.09 | .70 | 1.27 | .65 |

*Note*. HK is Hong Kong; 'Sci' is an abbreviation for Science; Science included social sciences (e.g., Economics); 'Native lang' is an abbreviation for Native Language; 'Hum' is an abbreviation for Humanities; 'Perf Ratings' abbreviated performance ratings; 'Add Quals' abbreviated additional qualifications.

Table 2

*Mean Cell Duration Values for Attractor Selection*

| | Gaze behaviour | | | | |
|---|---|---|---|---|---|
| Didactic event | Focused gaze | Scan | Student material gaze | Teacher material gaze | Other gaze |
| Address behaviour | 48.68 | 2.98 | 18.00 | 13.10 | 22.61 |
| Interacting | 114.94 | 15.82 | 10.46 | 32.33 | 38.82 |
| Talking | 77.17 | 13.66 | 10.85 | 43.80 | 29.30 |
| Refer to notes | 24.47 | 4.63 | 5.48 | 44.51 | 11.30 |
| Logistics | 1.75 | .84 | .76 | 15.09 | 1.71 |

*Note*. Mean cell durations for each state space grid cell. These values were used for identifying ‘attractors’: that is, universally prevalent didactic gaze events. These mean values are raw scores, with no adjustment for class size as covariate.

Table 3

*Descriptive statistics before and after data transformation*

| | | Untransformed | | Transformed | |
|---|---|---|---|---|---|
| **Expertise feature** | **Variable** | **M** | **SD** | **M** | **SD** |
| Knowledge | Attentional student gaze | 1.82 | 1.11 | 1.27 | .38 |
| | Attentional non-student gaze | .84 | .33 | .90 | .18 |
| | Communicative student gaze | 1.14 | .68 | 1.00 | .35 |
| | Communicative non-student gaze | 1.23 | .93 | 1.03 | .37 |
| Efficiency | Attentional gaze efficiency | 2.49 | .94 | 1.55 | .27 |
| | Communicative gaze efficiency | 2.91 | 1.02 | 1.65 | .30 |
| Flexibility | Attentional transition entropy | 45.42 | 39.93 | 5.96 | 2.71 |
| | Communicative transition entropy | 41.68 | 37.18 | 5.74 | 3.11 |
| Strategic consistency | Gaze consistency | .86 | .06 | .93 | .03 |

*Note.* Transformed data was all square-root transformed. All means have been adjusted with class size as covariate.

Table 4

*Summary of discriminant analyses for teachers' attentional gaze durations*

| Predictor | Parallel Discriminant Ratio Coefficients | | | Univariate F (3, 36) | Within-group correlations | |
|---|---|---|---|---|---|---|
| | Function 1 | Function 2 | Function 3 | | ASG | ANG |
| Class size (Covariate) | .79 | .08 | .13 | 17.17 ** | .29 | -09 |
| Attentional student gaze (ASG) | -.97 | .65 | .14 | 5.78 ** | | .29 |
| Attentional non-student gaze (ANG) | -.23 | .27 | .74 | 2.47 * | | |
| Canonical $R^2$ | .67 | .32 | .0001 | | | |
| Eigenvalue | 2.01 | .47 | .00 | | | |

*Note*. * *p* <.10, ** *p* ≤ .001

Table 5

*Summary of discriminant analyses for teachers' communicative gaze durations*

| Predictor | Parallel Discriminant Ratio Coefficients | | | Univariate F (3, 36) | Within-group correlations | |
|---|---|---|---|---|---|---|
| | 1 (Culture) | 2 (Expertise) | 3 (Other) | | CSG | CNG |
| Class size (Covariate) | .09 | .11 | .04 | 17.19 ** | .03 | -.36 |
| Communicative student gaze (CSG) | -.05 | -.43 | .49 | 3.52 * | | .27 |
| Communicative non-student gaze (CNG) | -.03 | -.44 | .47 | 3.27 * | | |
| Canonical $R^2$ | .66 | .38 | .04 | | | |
| Eigenvalue | 1.94 | .62 | .04 | | | |

*Note*. * p < .05, ** p < .001

Table 6

*Dispersion (i.e., inconsistency) of teacher gaze strategy in each teacher group.*

| | Dispersion (0-1) | | sqrtDispersion | | Class size | |
|---|---|---|---|---|---|---|
| | *M* | S.D. | *M* | S.D. | *M* | S.D. |
| HK | | | | | | |
| Expert | .84 | .07 | .92 | .04 | 33.90 | 4.20 |
| Novice | .89 | .04 | .94 | .02 | 33.60 | 3.50 |
| UK | | | | | | |
| Expert | .82 | .10 | .92 | .03 | 21.90 | 6.33 |
| Novice | .89 | .03 | .94 | .01 | 20.80 | 7.05 |

*Note*. Although the expertise differences within each culture are comparable, it is likely that the differing class sizes across cultures accounted for only the UK expertise differences being significant and not those in Hong Kong. These are raw means that have not been adjusted with class size as covariate.

**Figures**

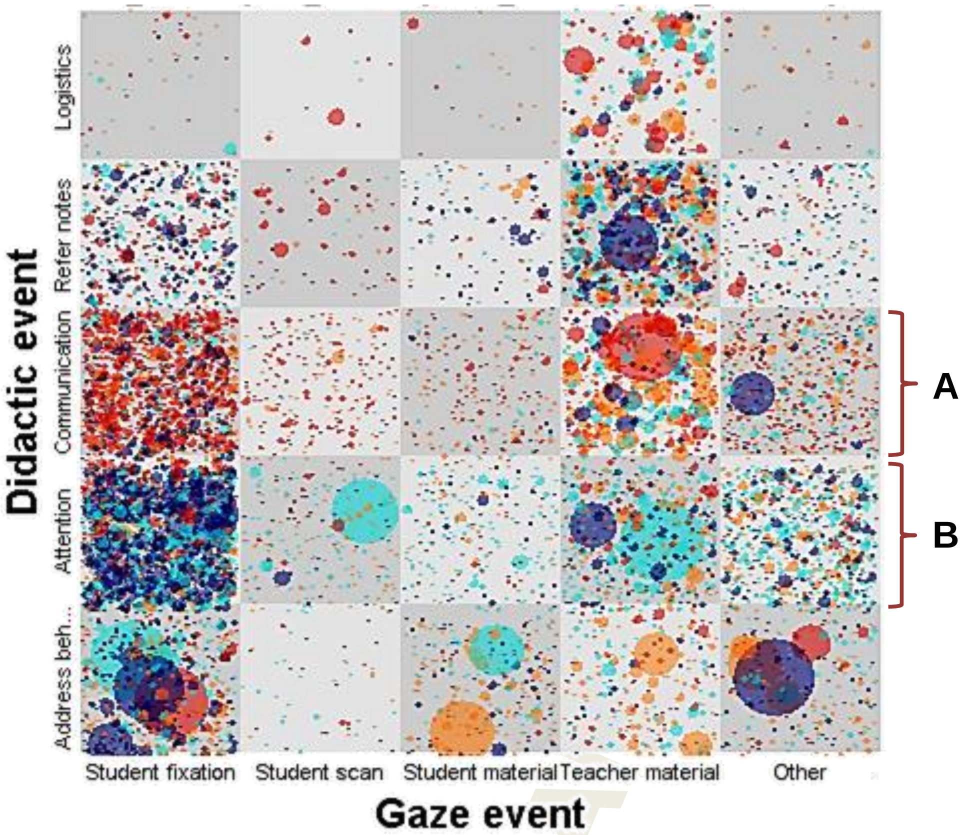


*Figure 1*. The state space grid of teachers' didactic gaze (raw data). Each node represents one visit; the size of the node shows the duration of that visit. Western teachers are in blue; Eastern teachers in red. Experts are in the darker shade; novices in the lighter shade. Row A represents communicative gaze which occurs during teacher lecturing; row B represents attentional gaze which occurs during teacher questioning.

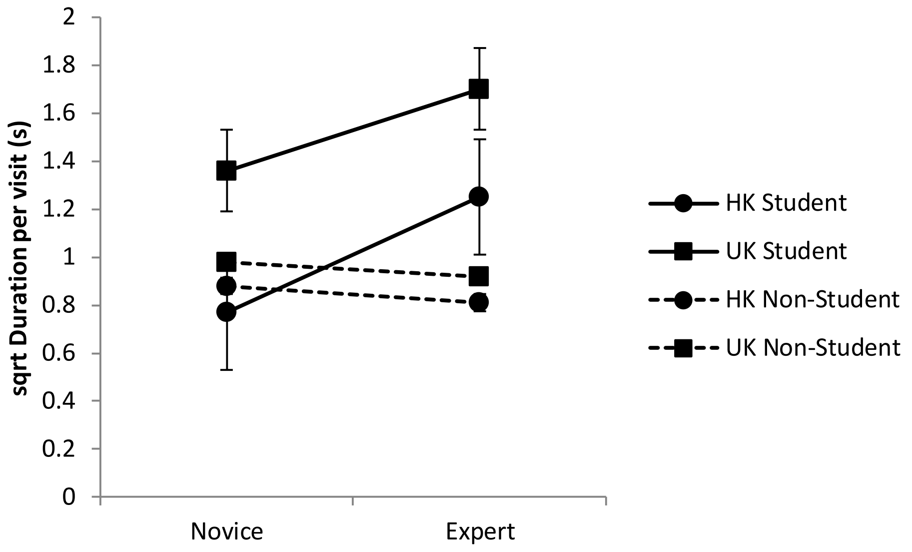


*Figure 2.* Teachers' mean attentional gaze duration per visit (i.e., occasion), representing knowledge. Error bars show standard errors. Means adjusted for covariate.

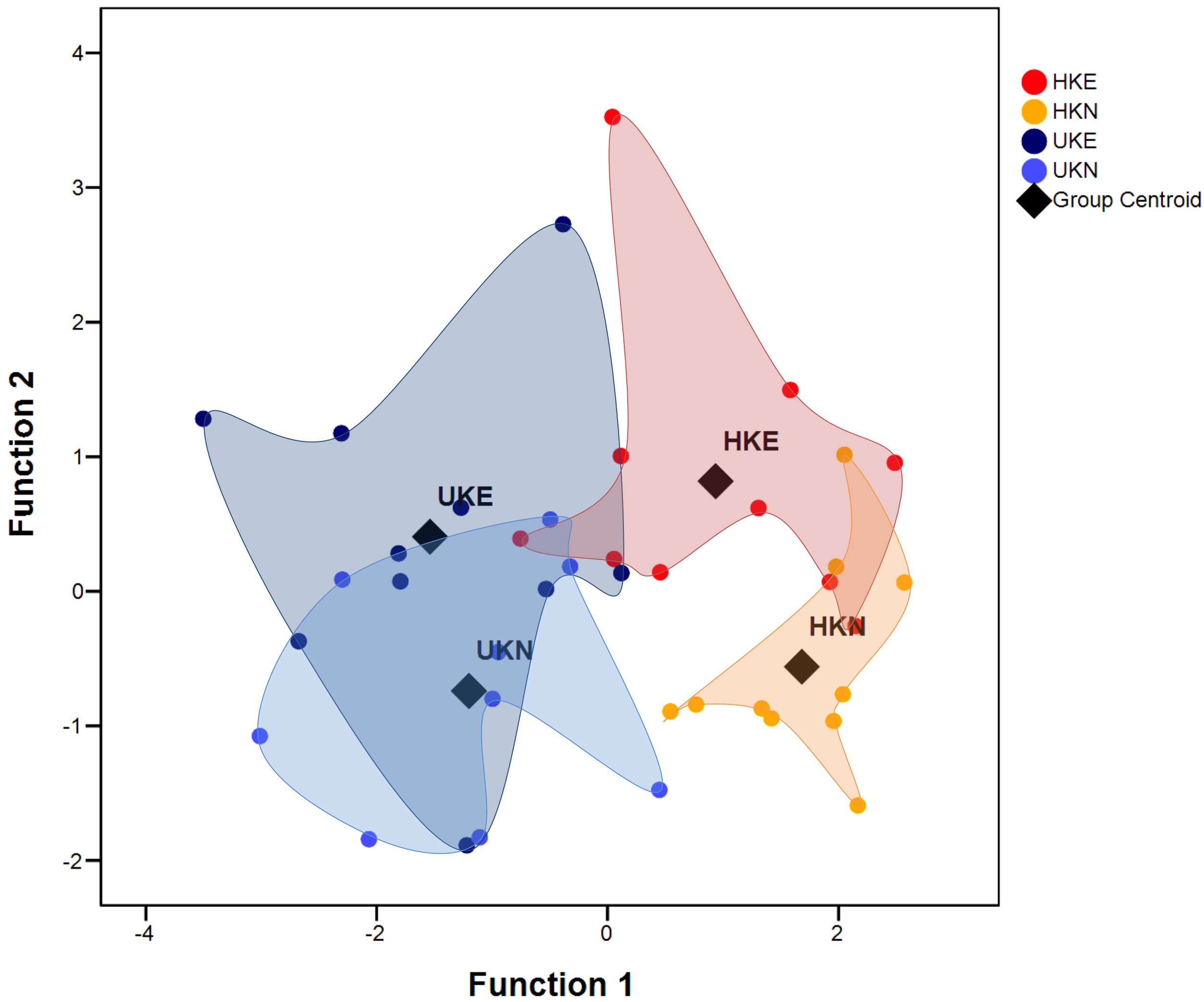


*Figure 3.* Scatterplot showing discriminant functions for attentional gaze durations of each teacher group. HKE = Hong Kong experts, HKN = Hong Kong novices, UKE = UK experts, UKN = UK novices.

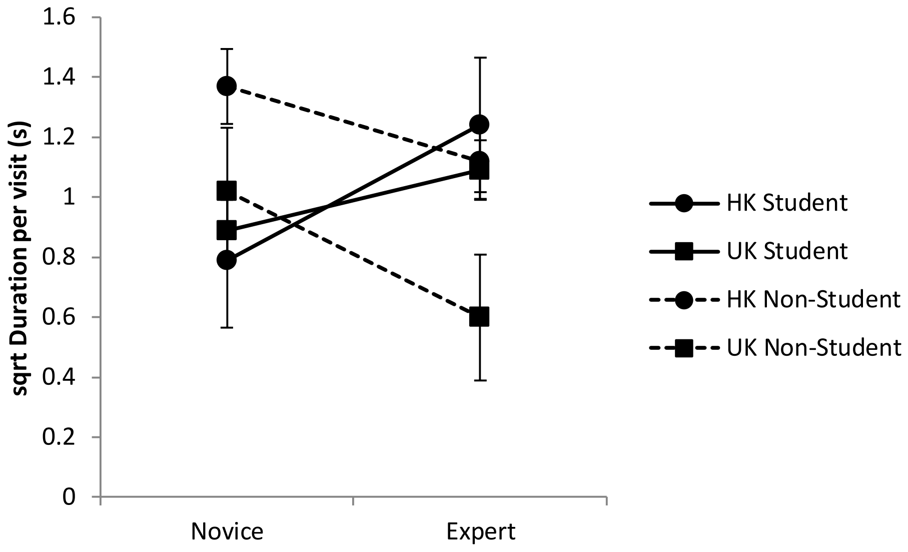


*Figure 4.* Teachers' mean communicative gaze duration per visit (i.e., occasion), representing knowledge. Error bars show standard errors. Means adjusted for covariate.

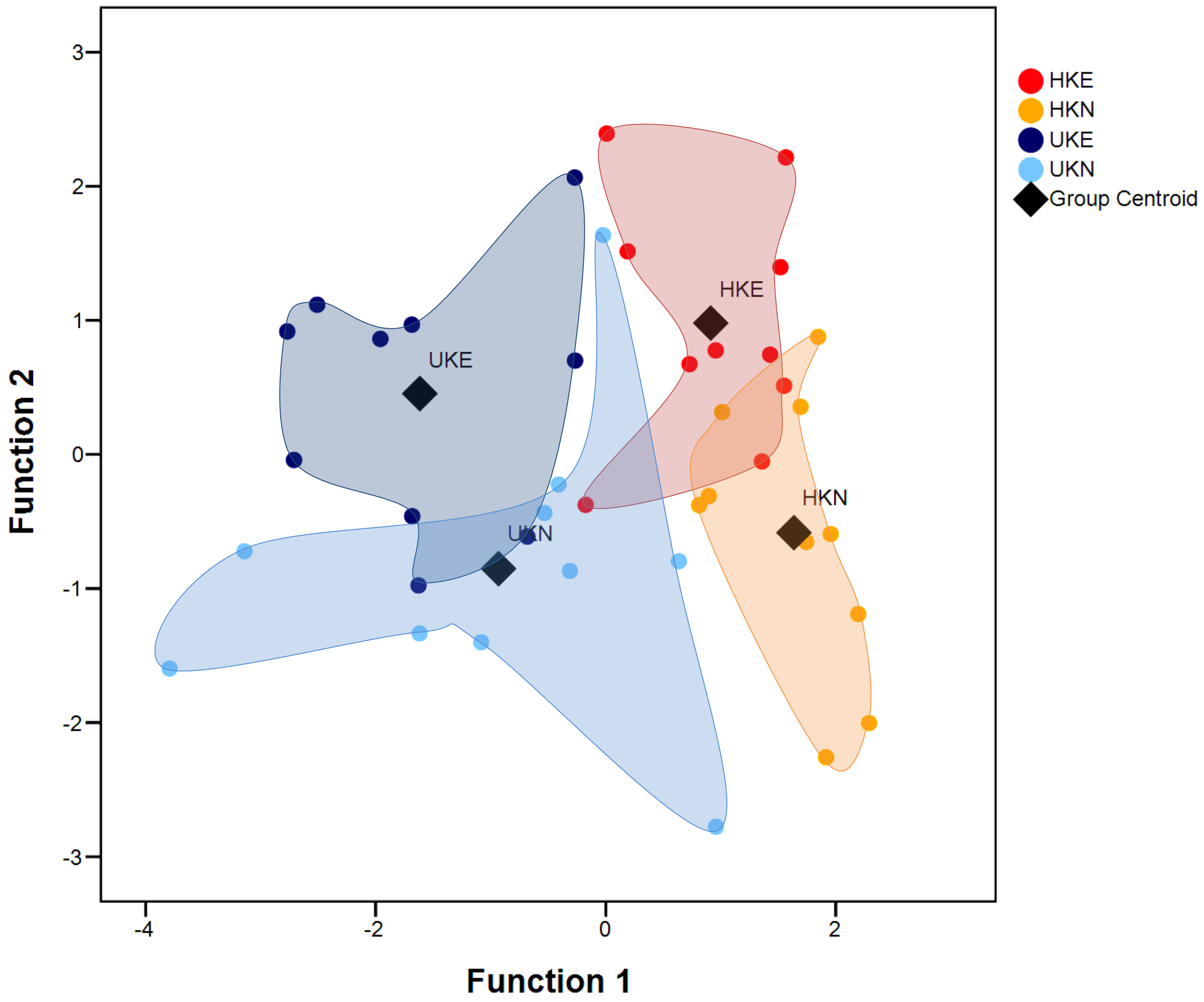


*Figure 5.* Scatterplot showing discriminant functions for communicative gaze durations of each teacher group. HKE = Hong Kong experts, HKN = Hong Kong novices, UKE = UK experts, UKN = UK novices.

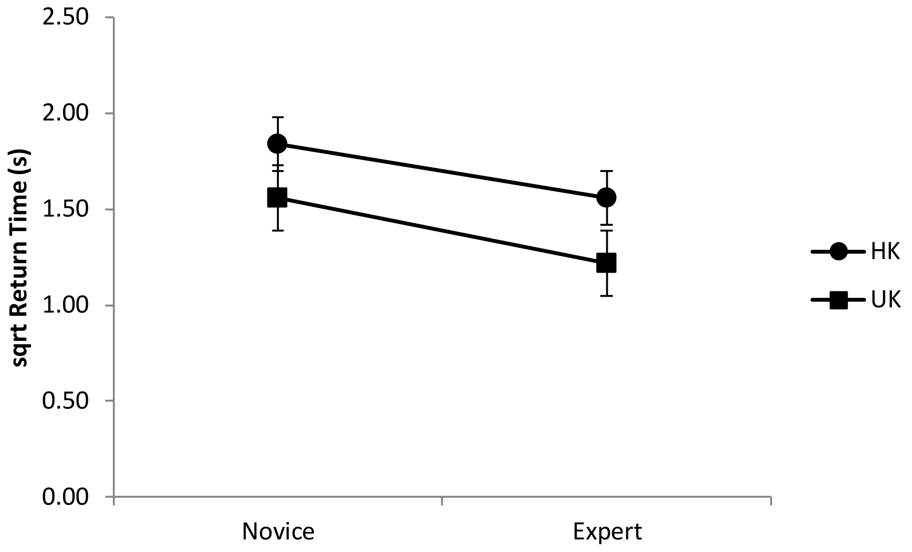


*Figure 6*. Mean return times during teachers' attentional gaze, representing gaze efficiency (with shorter return time being stronger efficiency). Error bars show standard errors. Means adjusted for covariate.

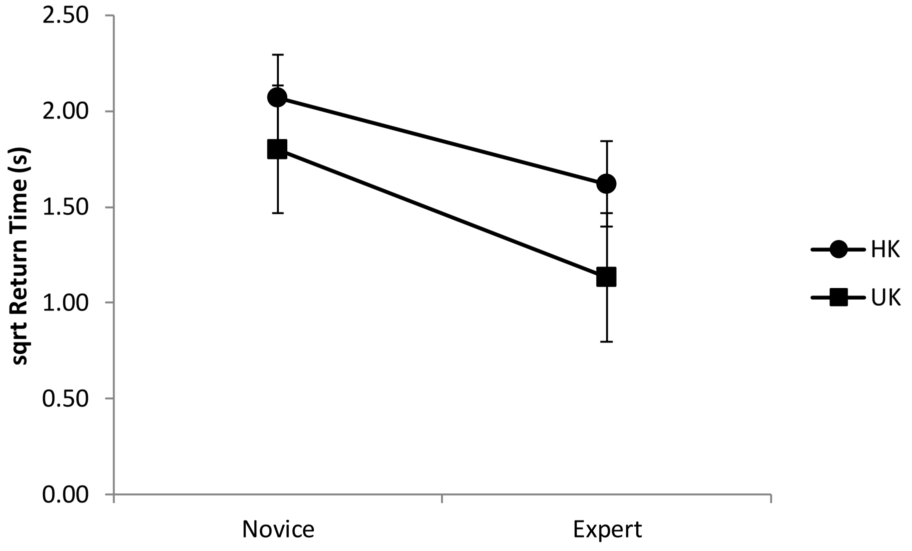


*Figure 7*. Mean return times during teachers' communicative gaze, representing gaze efficiency (with shorter return time being stronger efficiency). Error bars show standard errors. Means adjusted for covariate.

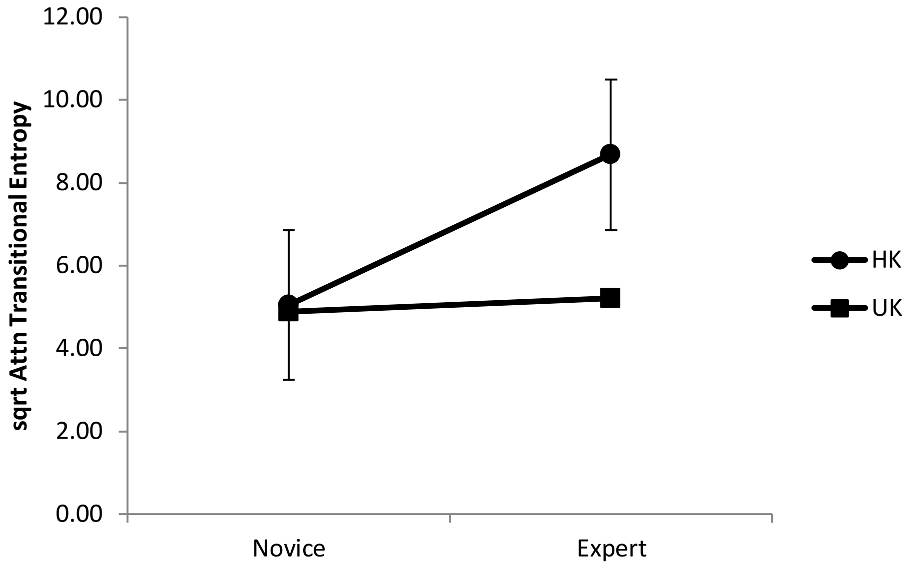


*Figure 8.* Mean regional transitional entropy during teachers' attentional gaze, representing gaze flexibility (with higher transition rate being greater flexibility). Error bars show standard errors. Means adjusted for covariate.

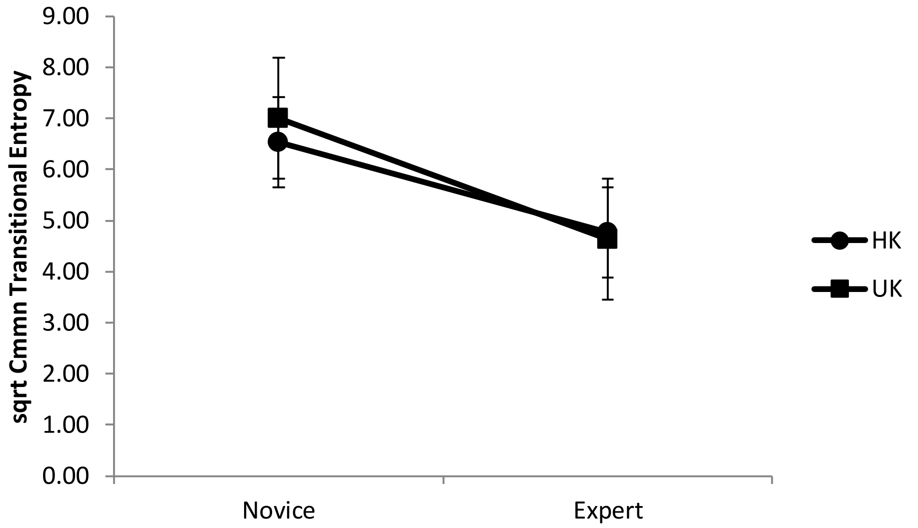


*Figure 9.* Mean regional transitions during teachers' communicative gaze, representing gaze flexibility (with higher transition rate being greater flexibility). Error bars show standard errors. Means adjusted for covariate.